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SURGERY

ITS PRINCIPLES AND PRACTICE

BY VARIOUS AUTHORS

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SURGERY

ITS PRINCIPLES AND PRACTICE

CHAPTER XXV

THE SURGERY OF THE MUSCLES*

By J. F. Binnie, M. A., C. M., F. A. C. S.,
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GAS GANGRENE

During the Great War injuries to muscles were of special importance because it was in them that the dreaded gas gangrene most commonly developed. Soon after injury the course of a projectile (especially a fragment of shell) through a muscle was recognized not only by the laceration, but by the "cooked" appearance of the injured tissues, and by the failure of the involved muscle to contract on stimulation by the scissors or knife during débridement. Foreign bodies, such as projectiles, stones, clothing, etc., were usually present except in simple through-and-through wounds from rifle bullets.

Bashford[1] found that around the track of the projectile there was merely a narrow zone of dead and disintegrated muscle which was healthy except that the fibers close to those killed showed an increased distinctness of the longitudinal and a lessening of the transverse striations. There was also some localized proliferation of the sarcolemma nuclei.

René Sand[2] found at a distance from the wound changes similar to those described by Bashford as existing close to the track of the projectile, but that these changes which he attributed to "shock at a distance" were transitory. Contusion and compression of the tissues in addition to the changes already described caused interstitial hemorrhages and occasionally necrosis. Curiously enough, ischemia from destruction of the arterial supply led to an exaggeration of the transverse striation with necrosis, mummification, and segmentation of muscle-fibers. Such are the ordinary tissue changes in the injured muscles uncomplicated by infection.

Every wound is, however, contaminated and its subsequent course depends: (1) On the character and extent of the wound. (2) On the

* Supplementary to Chapter XXVII, Vol. II, p. 435, and Chapter CIII, Vol. VI, p. 212. Compare Wallace's Chapter on Gas Gangrene.

resisting power of the patient. (3) On the time when treatment is begun and the character of the treatment adopted. (4) On the character of the infection.

(1) **The Character and Extent of the Wound.**—Simple through-and-through bullet wounds are often innocuous, but even in such it is wise to enlarge the wound, especially that of entrance, because frequently the muscle is pulped under the fascia, and unless properly treated forms an excellent pabulum for the growth of anaërobic bacteria. Large lacerated wounds, especially those in which fragments of metal, stone, and clothing are embedded, are the most dangerous. Hemorrhages from such vessels as the posterior tibials add greatly to the dangers by increasing destruction and producing pressure ischemia.

(2) **The Resisting Power of the Patient.**—Soldiers in the United States Army were physically the cream of the male population, and their course of training was such as to raise their resisting power to a very high degree. A series of 57 autopsies performed on men who died at various periods after being wounded gives very striking results.[3] The subjects were: Belgians, 23; French, 18; British, 14; Algerian, 1; German, 1. Of these, 26 survived their injury one day or less, and 31 more than one day.

TABLE SHOWING PERCENTAGE OF NORMAL AND SCLEROSED LIVERS AND KIDNEYS IN 57 AUTOPSIES

	Liver Sclerosis.			Kidney Sclerosis.			Liver and kidney normal in same subject.
Age.	Normal.	Beginning.	Confirmed.	Normal.	Beginning.	Confirmed.	
19–20 years....	60	40	..	60	40	..	40
21–30 years....	45	45	10	32.5	57.5	10	20
31–40 years....	10	50	40	10	40	50	10

If these figures are even approximately correct, they show that slight sclerotic changes in the liver and kidneys are present in an unexpectedly large number of young men who are apparently in perfect health. Such latent pathologic conditions may well lower the resistance of their subjects and may explain to some extent why of two similar individuals who have suffered similar wounds, have been similarly exposed to infection, and have been treated identically, one succumbs to the infection and the other overcomes it. Overwork, exposure, hunger suffered before being wounded lowers resistance, while shock, hemorrhage, exposure, hunger, and delay may soon make a strong man become a poor surgical risk.

(3) **The Time When Treatment is Begun and the Character of the Treatment Adopted are Both of Great Importance.**—Every wound is contaminated, but it takes time for the infective agents to multiply in and act on the tissues. This time varies from a very few hours up to a day or two, depending upon the virulence of the infection,

the amount and character of tissue destruction, and the resisting power of the individual. It is obvious that the sooner the treatment is begun, the better.

In the field and in the Triage or Field Hospital apart from attention to hemorrhage the treatment ought to be the application of protective dressings and splints, giving of antitetanic serum, combating shock, and getting the patient to the Evacuation Hospital (or C. C. S.) as quickly as possible. In the Evacuation Hospital the principles underlying the treatment of all muscle wounds are free exposure of all parts of the wound, excision of all devitalized tissue and foreign bodies, and the application of suitable dressings. The wound should be left wide open unless circumstances permit the patient being retained for observation, in which case the wound may often be treated by immediate closure.

Débridement or thorough removal of all devitalized tissues is one of the lessons of the war which will be of permanent value in civil practice in which complete or partial primary closure will be the rule.

(4) **The Character of the Infection.**—As already stated, every wound is contaminated by infective agents, but a period (usually hours) is required before the infective agents make themselves at home, multiply, and become actively pathogenic. It is during this period that radical débridement is most conservative, as by its means are removed not only the infective organisms but also the dead and injured tissues which would constitute their culture-medium. All varieties of pathogenic organisms may be present, but in war wounds the most dangerous bacteria are the streptococci and the anaërobes. Devitalized muscle is the pabulum *par excellence* for anaërobic bacteria. Hemolytic streptococci are not only extremely noxious *per se*, but they prepare the soil for and favor the growth of the anaërobes.

In 72 out of 100 open wounds examined from two to twenty-two days after infliction anaërobic bacteria were found by Henry.[4]

Saccharolytic anaërobes, of which the most important is the B. welchii (B. perfringens), grow very rapidly in fermentable carbohydrates and produce acids and gas. As muscle contains 1 per cent. carbohydrates it forms, when devitalized, an excellent culture-medium.

Proteolytic anaërobes—*e. g.*, B. sporogenes, B. histolyticus, B. tetani—grow more slowly.

The characteristic gas is produced by the action of the toxins on the muscle-fibers and is really a late phenomenon of the infection, and yet may be discovered clinically in from four to six hours after injury.

A number of surgeons experienced in Evacuation Hospital work have noted that wounds infested by maggots rarely develop gas gangrene. The first atrociously "maggoty" wound seen by myself at Chateau-Thierry happened to be also the site of very bad gas gangrene. When gas is present subcutaneously it probably has escaped from the muscle.

Clinically gas gangrene presents itself in three types: 1, Fulminating; 2, common; 3, delayed.

1. **Fulminating Type.**—Before the patient has recovered from the shock and initial hemorrhage of his wound, gas gangrene develops fully and in a few hours the condition may be hopeless. The patient is cold, pale, restless. There is cyanosis of the mucous membranes and of the extremities. Vomiting is common. The pulse is imperceptible. Locally the wound has the characteristic smell and appearance of dead muscle. The skin is discolored and much gas is present. Death generally ensues in ten to twenty-four hours. Treatment is usually unavailing—the toxemia is too great.

2. **Common Type.**—The wounded man has usually lain in the field for many hours, and when he reaches the Evacuation Hospital he has the appearance of a very sick man. The temperature is elevated and pulse rapid. The skin, at first flushed, becomes pale, and later lemon colored. The eyes are icteric. Vomiting is common and persistent, becoming toward the end black because of petechial hemorrhages in the stomach. The tongue is dry and foul. The mentality is clear. As Emrys Roberts and Cowell write, "It is not uncommon to see a man smoking a cigarette or reading a paper a few moments before death."

Locally the skin is tense, reddish, later dusky violet. The discoloration spreads and blisters appear. As lytic changes take place the greens and blacks of decomposition become evident. On operating one finds the surface of the track of the wound moderately hard, pale, and non-contractile. Fine pink lines pass radially along the perifascicular spaces, showing spreading of the infection. This spreading takes place inside the muscle sheath and may be confined to one muscle. A greenish turbid lymph is commonly present beneath the fascial sheaths. The disagreeable pungent odor is characteristic (sulphurated hydrogen plus other volatile bodies). The chief site of gas formation is below the surface and it is a rather late phenomenon. The muscle lacks luster and translucency, looking somewhat like cooked meat. Later the tissues soften, become pulpy, and present a sequence of colors—red, pink, gray, green, and black. As lytic changes occur toxemia increases. Unless properly treated death almost invariably ensues within twelve to forty-eight hours from rapidly increasing circulatory failure the result of toxemia. The death is often sudden, as if from pulmonary embolism, but pulmonary embolism is not present.[4] While Henry's observation is probably correct in general, yet Krall found pulmonary embolism present in a man who died from anaërobic infection following traumatic arteriovenous aneurysm of the left popliteal vessels. The pulmonary embolus was full of the Welch bacilli.

3. **Delayed Type.**—This type appears days or weeks after operation. One notices that the wound is not granulating normally, that a pungent smell is present, then that general constitutional symptoms arise. The local and general course of events is practically the same as in the common type. One of the worst cases of the delayed type seen by myself was under the care of H. S. Valentine. The patient arrived at Base Hospital No. 28 apparently in good condition, with a large

débrided wound in the anterior part of the thigh. After a short time the wound was closed by suture and apparently healed. Two weeks after suture severe hemorrhage took place and gas gangrene of the adductor muscles was found. The affected muscles were excised, hemorrhage controlled, the wound treated with 2 per cent. solution of picric acid in alcohol, and the patient recovered.

Treatment.—The best treatment is prophylactic, viz., early, thorough, and thoughtful débridement plus general supportive measures. When the disease has developed it should be attacked early and thoroughly. Amputation is often necessary, but often it may be avoided by excision of the affected muscles and by keeping the resultant large open wound clean.

Krall, in the laboratory, and various surgeons, in Base Hospital No. 28, found that picric acid in alcohol applied to such wounds played a useful rôle in overcoming those infections by hemolytic streptococci which increase the deadliness of the anaërobes.

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CHAPTER XXVI

THE ENDOCRINE SYSTEM OF GLANDS

By P. P. Vinson, M. D.,
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During the last thirty-five years rapid advances have been made in all branches of medicine and surgery, but no one study has made more progress and has been of more interest to the clinician and the surgeon than the study of the so-called endocrine glands.

For many years these glands were called the chromophilic system on account of their staining characteristics, and later they were commonly known as the ductless glands, as distinguished from the glands that supply their secretion to the body through a well-defined duct. Now we know these glands as the glands of internal secretion, or the endocrine glands.

Probably little would be known today about internal secretions if it were not for the fact that variation in the amount of secretion from these glands is so frequently observed, and the symptoms in many cases are so clearly recognized and associated with well-known processes occurring in the glandular elements. What group of symptoms is more distinctive and interesting than those seen in a well-defined case of exophthalmic goiter, or what disease presents such characteristic findings as acromegaly?

Recent advances in laboratory investigation have been of extreme value in recognizing mild disturbances of the secreting glands, and this has added interest to the whole problem and has made diagnosis more exact.

In considering these glands one must bear in mind their association with the vegetative nervous system, although at present this relation is far from being definitely settled. The interglandular relationship is also quite undetermined. The four glands that are of prime importance in this discussion are the thyroid, the parathyroids, the suprarenals, and the pituitary. Besides these are the thymus, the spleen, the coccygeal and pineal glands, and the carotid bodies. Very little is known concerning the physiology and pathology of this latter group, but no doubt our interest in these glands will increase with refinements in diagnosis, and their functions will be as clearly understood or even more so than the functions of the thyroid.

The Thyroid Gland.—The gland that has stimulated the greatest interest is, of course, the thyroid. This has been due to several reasons. The prominent location of the gland, the usual enlargement with overactivity and the profound increase in body metabolism which accompanies this overactivity, have been the chief factors in causing intensive

study of its actions. The amelioration of symptoms following a partial removal of the overactive gland and the development of symptoms now recognized as myxedema, following the complete removal or destruction of a normal or overactive gland, have been important steps in endocrinology and have finally led to the identification and isolation of the thyroid hormone, "thyroxin," by Kendall. (*Vide* his chapter on the Chemical Nature of the Thyroid Secretion, also C. H. Mayo's chapter on the Surgery of the Thyroid.)

Hyperactivity of the thyroid can be present without glandular enlargement, but a microscopic study always shows characteristic changes in its morphology.

Underactivity of the thyroid is recognized as cretinism—a congenital absence or hypofunction of the gland—and as myxedema—an acquired marked reduction or absence of the thyroid secretion.

With recent studies in basal metabolism early manifestations of these disorders may be recognized and treatment with mathematic precision may be instituted.

The administration of thyroxin to animals, as well as to man, raises the metabolic rate, and in excess produces symptoms identical with those of hyperthyroidism. Thus from one of the endocrine glands which was veiled in mystery until a few years ago has been isolated a definite chemical compound which may be extracted not only from the gland itself, but be made synthetically in the laboratory.

The Parathyroid Glands.—The recent fundamental knowledge gained in the physiology of the thyroid has stimulated new interest in the parathyroids. The brief space allotted to the subject in this volume necessitates reference to Dr. C. H. Mayo's comprehensive chapter in Vol. VI, p. 343.

The parathyroid hormone, if such a chemical substance exists, has not been isolated, which implies that the physiology of these bodies is as yet hypothetic. Impressions as to their function are based almost entirely on the syndrome attending parathyroidectomy, and on hemorrhages into the parathyroids which destroy their structure. In Kendall's investigation of thyroxin (thyroid active principle) a very interesting and feasible hypothesis has been evolved.

It has long been known that basic salts, such as calcium chlorid and dilute acids, tend to control to a greater or lesser degree the involuntary tonic muscular contractions known as tetany. This at once suggests that these substances, in a measure at least, do what the absence or diminution of the parathyroid hormone, actual or relative, has failed to do. The production of urea from products of protein metabolism is reasonably a cellular one in view of recent biochemic conceptions. Is it not possible that parathyroid deficiency, actual or relative, may result in the accumulation of an excess of detoxified ammonium derivatives responsible for the attending clinical syndrome? More concerted work is necessary, however, to substantiate this hypothesis.

Clinical tetany is too well recognized to be discussed here in detail. It is interesting to note that occasional cases are observed simulating

true symmetric tetany which are unmistakably manifestations of hysteria. Their occurrence early in patients on whom thyroidectomy has been done often makes the differential diagnosis uncertain at first.

The treatment of tetany consists wholly in the administration of basic salts; calcium chlorid and the lactate are very satisfactory. They may be administered orally or intravenously.

The **pituitary gland** is probably next in importance to the thyroid, and with recent advances in brain surgery operative treatment of its disorders has been most gratifying. The gland is divided into two lobes, an anterior and a posterior. We are chiefly concerned with the anterior lobe, but changes in the posterior lobe may secondarily produce alterations in the function of the anterior lobe. As with the thyroid, two disturbances of secretion are recognized clinically—one an undersecretion and the other an oversecretion. With oversecretion comes acromegaly, and with undersecretion, the asexual type of person. Much confusion has existed concerning these variations in secretion, because in the case of a tumor of the gland an oversecretion may first occur, and later, from pressure probably, the secretion may be reduced below normal and the patient manifest the phenomena of hypopituitarism. Although the extreme fluctuations in the basal metabolic rate that are found in thyroid disorders do not occur in these cases, moderated disturbances of metabolism do occur, and this has been of great value in establishing a diagnosis.

Pituitrin, the extract from the anterior lobe of the pituitary gland, has well-defined actions and uses, especially in obstetric practice. Injections of pituitrin produce contractions of involuntary muscle, particularly that of the uterus, and cause a marked rise in blood-pressure.

Studies on the **suprarenal** or **adrenal glands** have shown their function quite conclusively, not so much from a hyperactive standpoint as with the thyroid, but rather concerning their lessened activity. Unfortunately, the suprarenal secretion has not yet been studied as has the active principle of the thyroid, and little is known concerning its chemistry. The cases of undersecretion are not so amenable to treatment as are the cases of hypothyroidism. The suprarenals are thought to be associated more or less closely with the thyroid, but much study will be necessary to produce conclusive evidence that this assumption is correct. (*Vide* Mann's chapter on the Adrenals.)

Various symptoms have been attributed to the overactivity or underactivity of the spleen, the thymus, and the other glands of internal secretion mentioned in the second group, and some of the more enthusiastic internists are inclined to believe that almost every organ has an internal secretion. This may be true, but no evidence has yet been presented to warrant such sweeping claims.

Much has been learned in a comparatively short time concerning this most interesting and absorbing subject, but more remains to be done. Surely no other field is quite so enticing to the well-trained clinician or surgeon, assisted by the modern physiologic chemist.

CHAPTER XXVII

SURGERY OF THE THYROID*

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Recent investigations of the endocrine glands have contributed so much with regard to the importance of their function that it seems advisable to record the development of the surgery of the thyroid as related to these findings.†

The importance of the thyroid is recognized clinically when we see the failure of development, physical and mental, in those born without it, as cretins, those with consuming energy caused by a hyperplastic gland, and those with myxedema who have lost the function of the gland in adult life. It is of interest to call attention to nature's marvelous provision for maintaning the circulation of the thyroid, which is far greater than that of any other gland. Under normal conditions the blood of the body circulates through the gland once an hour, and the most frequent anomalies are those which increase this circulation.

The thyroid develops from a single anlage between the three portions of the tongue, a position later designated as the foramen cæcum. The gland should be in its permanent place by the seventh week of fetal life; in descending it crosses the line of the developing hyoid bone. Rarely the gland remains in the tongue, and forms a rounded body or colloid goiter which quite fills the posterior portion of the organ, and in the enucleation of which the colloid material only should be removed; the more radical the procedure in such cases, the more surely will patients develop myxedema. Forty odd per cent. of thyroids are caught in their descent by the developing hyoid, which causes a stringing out of the central portion of the gland, the pyramidal lobe, and, rarely, a bit of tissue connected with the foramen cæcum is left above the hyoid. This may pass to the midline over, under, or through the hyoid bone as a thyroglossal duct cyst, which delivers through the foramen cæcum like the rare thyroid duct of a few invertebrates. When the duct closes a midline thyroglossal duct cyst is found over the hyoid bone. The surgical cure of such cysts depends not alone on the removal of the external cyst, but also on the removal of that portion connected with the foramen cæcum, which is composed of embryonic cells with regenerative power. We have destroyed the upper portion

* Supplementary to Chapter XXXVIII, Vol. III, p. 336, and Chapter CXII, Vol. VI, p. 329.

† The reader is referred to the previous volumes of this work for a full description of the embryology, anatomy, physiology, etc., of the thyroid.

with the cautery; in some instances it has been removed by dissection[20] (Figs. 1–3).

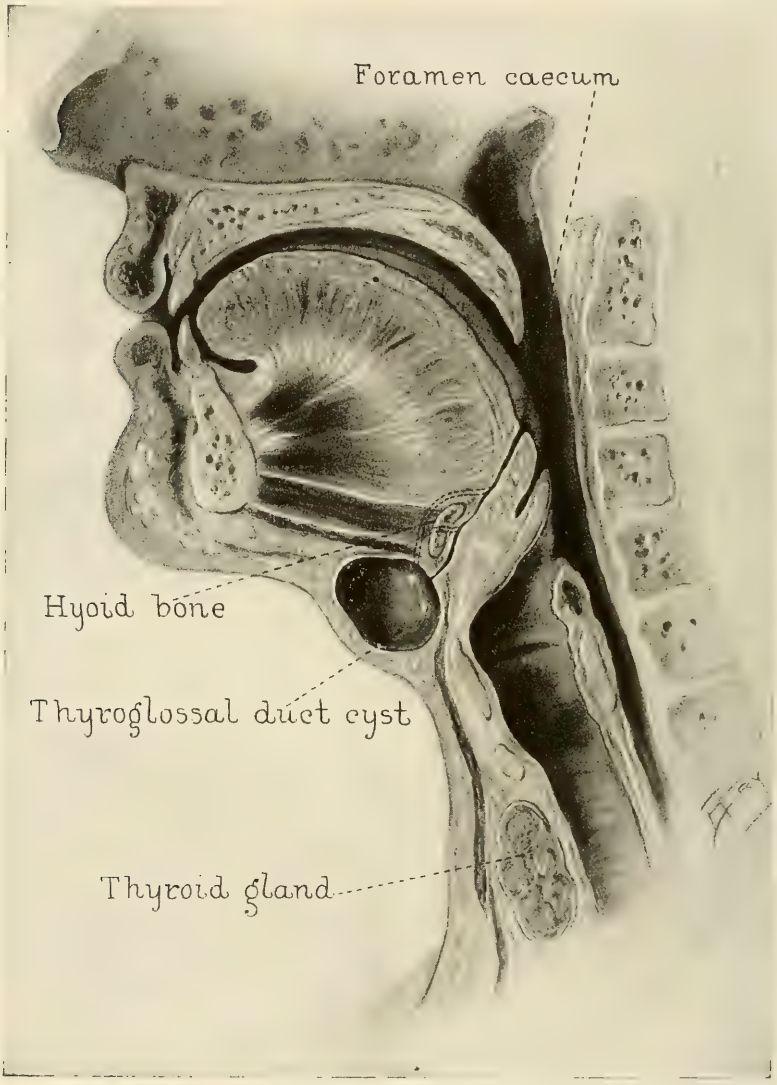

Fig. 1.—Thyroglossal Duct Cyst. Stricture of Duct and Three Possible Routes Connecting with Foramen Cæcum.

ETIOLOGY

Long before the relationship of iodin to the secretion of the thyroid gland was determined by Baumann in 1895 it was known that iodin in some form had a marked beneficial effect on such goiters as the adolescent and the simple colloid. While treatment by iodin may be of great benefit in certain types of goiter, its use in cases of goiter of

long standing in persons more than forty-five may induce degenerative conditions even though it may reduce the size of the gland; in some instances it undoubtedly is the cause of thyrotoxic goiter, as pointed out many years ago by the late Theodor Kocher. While we do not know the true cause of changes in the thyroid, it may eventually be shown to be direct infection by bacteria, or by toxins from infections in other regions; and further investigation of colloid chemistry will undoubtedly add important facts. It has long been believed that the stimulatory agent is water-borne. Extensive investigation has been

Fig. 2.—Lingual Thyroid: Cross-section

made of this theory, particularly by Gaylord, Marine,[12] Lenhardt, and McCarrison. Seemingly such changes as hyperplasia interfere with the ability of the gland to make use of iodin.

Sudden shock or fear is often regarded as the cause of exophthalmic goiter, but is only a hook on which to hang the date of the first manifestations of hyperthyroidism in a person suffering from hypersecretion of the thyroid (Fig. 4). The metabolic test would have shown the hyperactivity at this time.

Wilson has shown in an extensive investigation of cervical sympathetic ganglions removed in the clinic from patients with exophthal-

FIG. 3.—LINGUAL THYROID.

FIG. 4.—EXOPHTHALMIC GOITER.

mic goiters and exaggerated exophthalmos (the Jaboulay and Jonnesco operation) and from patients with exophthalmic goiters coming to necropsy that a marked degeneration is present in the ganglion cells

which may prove important in etiology.[23],[24],[26] The Jaboulay and Jonnesco operation is now but rarely performed in the clinic.

Simple goiters are adenomatous, diffuse, or encapsulated. Medical or surgical treatment is advisable to give relief of symptoms, size, deformity, pressure on nerves or trachea, or to anticipate and prevent the toxic symptoms of later hyperthyroidism. Cystic goiter is rarely toxic, but becomes a nuisance by size and pressure.

Toxic adenomas have been shown by Plummer to be adenomas with hyperthyroidism; they represent approximately one-fifth of the clinically so-called exophthalmic goiters, designated in Wilson's pathologic report as adenomas with or without degeneration.[21] Boothby[3]

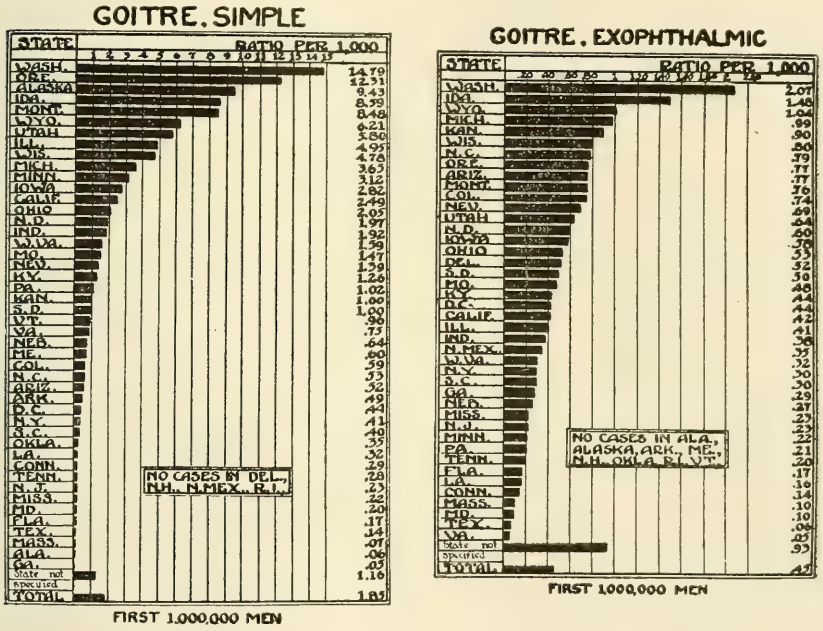

FIG. 5.—GOITER: SIMPLE AND EXOPHTHALMIC.

showed that those patients with adenomas with symptoms of hyperthyroidism more or less closely resembling exophthalmic goiter also have an increased metabolic rate. Kendall[25] showed that toxic adenomas like simple adenomas vary in iodin content, differing from the true hyperplastic gland of exophthalmic goiter in which Marine demonstrated a low content of iodin.[14] In foreign countries toxic adenomas are often mentioned as pseudo-Graves' disease, formes frustes, basedowized and incomplete exophthalmic goiter; little attention has been given them in this country except by H. S. Plummer and his co-workers. Plummer shows that the symptoms of toxemia appear in patients who have had goiters on an average of fourteen and one-half years, and the patients come for operation on an average

of three years later. They do not have exophthalmos, but have tachycardia, tremor, loss of weight, and nervousness which appear when the patients are from five to ten years older than the average patient is when the symptoms of exophthalmic goiter develop.

In 50 per cent. of the patients with exophthalmic goiter the eyes protrude within a few months; in approximately 90 per cent., within two years. Symptoms from gland activity do not necessarily mean marked enlargement of the gland. The hypertension is greater in adenoma with hyperthyroidism than in exophthalmic goiter. The relief obtained after operation is more complete and earlier in adenoma with hyperthyroidism.

Plummer states that hypertrophy and hyperplasia are probably not essential for the institution of mild hyperfunction. It is possible that the mitochondria of the thyroid cells, shown by Bensley, to pancreas, and the mitochondria of cells in adenomas, referred to by Goetsch, may be indicative of function, whether of secretion or proliferation is not determined.

In various sections of the United States goiter is becoming common and in some areas it is apparently endemic. The report from the Surgeon General's office on the results of examinations of the first million draft recruits shows that many goiters exist in the Great Lakes region and still more in the northwestern states (Fig. 5).

SYMPTOMATOLOGY

Adenomas of fetal type, encapsulated and of congenital development, frequently occur throughout the thyroid. They may remain small or grow to excessive size.

The gland with increase or hyperplasia of thyroid tissue without retention of secretion and colloid deposit is the true exophthalmic goiter. Various degrees of increased secretion causing several of the well-recognized symptoms of this disease may be found in both simple adenomatous goiter and in those which are becoming toxic with areas that are hyperplastic in the gland. The exophthalmos occurs with hyperplasia when it exists alone, rarely with a combination of other pathologic types in the gland, and in these cases the rapid heart is a steady heart until late in the disease, while in the thyrotoxic goiter both fine and coarse tremors are noted, and the heart fluctuates from temporary nearly normal action to irregularity in tension, rhythm, and rapidity. They represent about one-fifth of the so-called exophthalmic goiter patients.

Infected goiters with abscess development, with the general symptoms of acute infection and with local swelling, are rare; they require incision and drainage. Tuberculous infection also is very unusual; the gland is hard and may be from half again to twice larger than normal and quite symmetric. The hardness resembles that of malignancy; the symptoms are those of mild hyperplasia. In such cases we have removed all but the posterior part of each lobe of the gland, with good results. In operating for infection and malignancy the surgeon appre-

ciates the aid of a laboratory equipped for immediate report on frozen section material.

Carcinoma and sarcoma of the thyroid as found in various epithelial growths and the several types of connective-tissue tumors are fortunately rare in proportion to the great number of goiters reported in this country. Kocher in 1908 reported 309 malignant cases; up to that time 3500 operations for goiter had been performed in his clinic. Wilson[22] in 1917 found 132 malignant tumors in 9348 thyroids removed at operation in the clinic up to July 1, 1917. The disproportion in these statistics may be accounted for by the fact that the greater number of the cases in Wilson's series were exophthalmic, while the greater number in Kocher's series were simple. Carcinoma is to be suspected in the rapidly growing, irregular, and hard tumor of a long quiescent goiter in middle or late middle life, but hemorrhage in an adenoma may produce the same early symptoms. Only in the primary stage, while the carcinoma is still encapsulated, is it operable. The gland early becomes fixed, the growth soon involves its capsule and overlying muscles, and fixes the skin. Pressure on the recurrent laryngeal nerve causes hoarseness or loss of voice, and the pressure on the trachea may necessitate a low tracheotomy; even a long cannula tracheotomy tube may require lengthening if the growth penetrates beneath the sternum.

Sarcoma, a rounded tumor, is of more rapid growth than carcinoma, and by the time operation is attempted extirpation is only occasionally possible. Radium and *x*-ray treatments are indicated in both carcinoma and sarcoma, and Coley's toxins undoubtedly are of benefit in the sarcomas. In both conditions metastasis occurs early in the lungs and bones, especially in the bones of the head, and when malignancy is suspected an *x*-ray examination of the lungs and the bones usually involved should be made before operation is advised.

The use of radium and the *x*-ray in malignant conditions is apparently of considerable value, at least in checking the activity of cell division, or causing cell strangulation by the development of connective tissue.

Erhardt and Müller in a study of 238 cases of metastasis in malignant thyroids found carcinoma in the lungs in 48 per cent. and in the bones in 29 per cent., sarcoma in the lungs in 42 per cent. and in the bones in 18 per cent.

INDICATIONS FOR SURGERY

All types of goiter except the malignant may disappear spontaneously or during treatment, or they may be favorably affected by treatment. Many mistakes are made in the diagnosis of hyperthyroidism. Methods such as the use of epinephrin to differentiate or to accentuate symptoms are not satisfactory. The determination of the metabolic rate is an exceedingly valuable index to the severity of the disease. Surgeons rarely see the patients until they have been treated medically. The majority of operative cases are medical failures. Almost no other

disease capable of such serious consequences to the patient has as high a percentage of cures with as low a mortality.

The operation or the extent of operation to be performed for the relief of exophthalmic goiter in patients who are progressively growing worse and are in a serious condition and the preparatory treatment required are matters to be decided clinically, and, since Plummer has shown that the metabolic rate in the body is largely controlled by the thyroid, we have the means of more accurately determining the condition of these patients. Those patients with hyperplasia, according to the severity of the disease, are consuming at a rate of from 10 to 100 per cent. above normal, as shown by the added oxygen consumed and the increased carbon dioxid output. Nevertheless our judgment as to operability should be largely controlled by the state of improvement or nonimprovement of these patients, especially with regard to increase or decrease in weight. A patient with a metabolic rate of +40, who has lost weight and whose symptoms are increasing, is a more serious operative risk than the patient with a metabolic rate of +60 who has been worse and is now improving.

That the metabolic rate is increased in exophthalmic goiter (hyperplastic thyroid) was first shown by Müller and Magnus-Levy, and this has been confirmed in a few scattered instances by various observers. The true relationship of the activity of the gland to metabolism has been studied clinically and experimentally by H. S. Plummer and his co-workers. A summary of their findings was presented before the Association of American Physicians in 1917.

PREPARATION OF PATIENTS

According to Plummer the preparation for operation of patients with hyperplasia of the gland is often necessary before surgical procedures are undertaken. Rarely is emergency surgery indicated. The majority of patients may be operated on at the time they present themselves, but others who give a history of periods of activity and remission may come for operation during the most active period and with marked severity of symptoms; they are then medical and not surgical cases. Rest in bed, with an ice-bag over the heart and the goiter, digitalis, and all other means to sustain the patient through the ordinarily brief periods of these attacks, that is, a few weeks, will restore surgical indications. A patient who has been neglected and who fails to respond rapidly is sometimes benefited by the Porter method of injecting boiling water in areas throughout the gland. The water must be hot enough to coagulate albumin, otherwise it may stimulate the gland's activity and delivery; I have had a few deaths from this cause. The injection of quinin and urea serves the same purpose of causing an edema within the gland capsule. The metabolic rate, however, is rarely changed by such procedures, and we are finding less and less use for them. This also may be said of *x*-ray exposures, although the latter may give temporary, partial relief in cases of mild hyperthyroidism.

Through the work of Kendall[7] (*vide* his chapter) we now know the exact chemistry of the thyroid gland secretion, and since this gland is involved in the production of energy by the body, a test of the patient's metabolic rate gives the surgeon almost exact knowledge of the stage of the disease. This, taken into consideration with other clinical findings, gives very accurate information not only of the stage and severity of the disease but also of the dangers of operation. The physician is thus permitted to institute such treatment as will combat the symptoms or support the patient and enable the surgeon to judge as to the type of operation indicated. Ligation of the thyroid vessels has proved most beneficial in hundreds of our cases. It is expected that if the upper poles are ligated these patients will make an average gain in weight of 22 pounds in three months. The operation would only be indicated in patients in whom extreme symptoms and loss of weight are marked features. Injections or ligations are of benefit only for from a few months to two years at most, and gland resection is advised for permanent relief. Before the metabolic rate was used as a measure of the activity of the gland some idea of the condition of the patient was obtained by ligating the left upper pole one week before partial thyroidectomy; if the reaction which followed ligation was severe the right pole also was ligated without thyroidectomy a week later. The patient was allowed to go home for two or three months to improve, when a thyroidectomy of the right lobe, isthmus, and from one-half to two-thirds of the left lobe was performed. With more accurate knowledge of the condition of these patients fewer ligations are necessary.

With the present knowledge of the thyroid, its function and its diseases, medical treatment will undoubtedly assume greater importance. The goiters of adolescence respond to medical management, and many patients recover spontaneously. Further investigation must be made of the luetic goiter, which also responds favorably to medical treatment.

The prophylactic administration to thousands of school girls of iodid of sodium for periods of ten days twice a year is evidently of value (Marine[13]).

ANESTHESIA

A general ether anesthetic given with the open mask and plenty of air is preferred in our work, although some surgeons prefer nitrous oxid. Occasionally local anesthesia is indicated throughout the operation. To patients with hyperplastic glands we give one-half hour before operation from $\frac{1}{6}$ to $\frac{1}{4}$ grain of morphin and $\frac{1}{100}$ grain of atropin; the latter checks the tracheal and bronchial mucus. Local anesthesia, if indicated in any type of goiter by the condition of lungs or of the circulation, or other complication, is secured by the free injection of novocain, or a similar preparation, and adrenalin into the field of operation. Sometimes if the thyroid tumor presses on the trachea local anesthesia is best, even if the patient prefers to be asleep during the operation. Crile's method of making use of local anesthesia to relieve the sensitiveness of the skin is of value even with the general ether anesthesia, as less profound anesthesia may be employed during the early stage of the operation. The sensitiveness

of the tissues beneath the skin is very slight in comparison unless undue traction is made on them. Patients may be allowed to come out of the anesthetic at the completion of the operation before the closure of the wound, and the operator may test the ligatures by the movements and coughing of the patient. In this manner a secondary hemorrhage may be prevented.

OPERATION

The surgical assistants should be instructed to close artery forceps in line with nerves and not across them. This not only protects the nerves but also gives better control of the venules. After the resec-

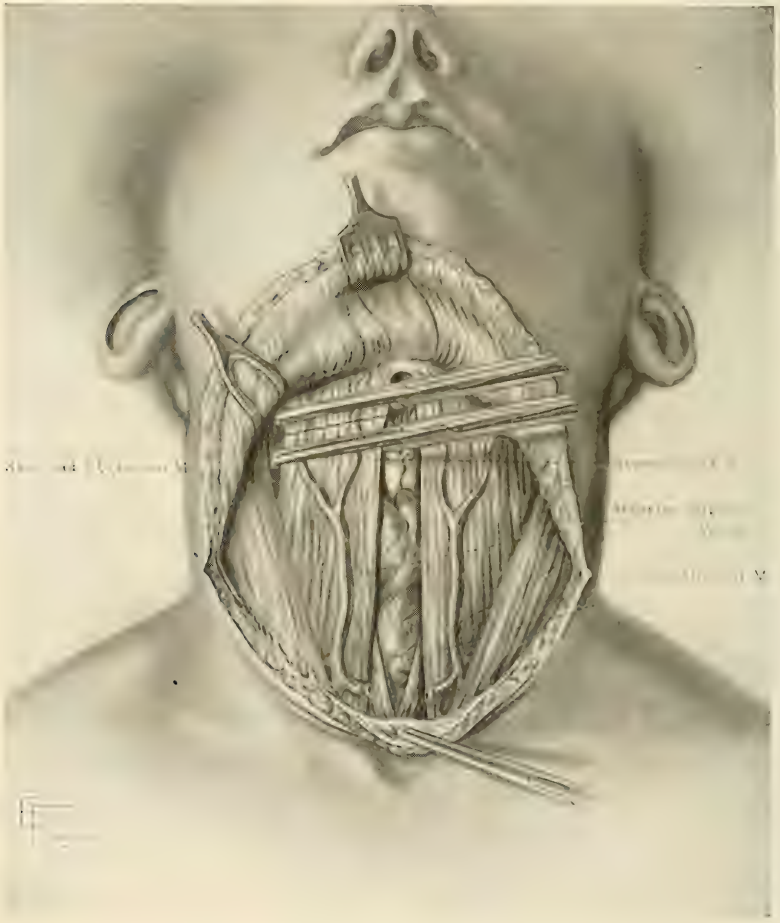

Fig. 6.—Exposure of Anterior Muscles, Cutting of Sternohyoid.

tion, in suturing the remaining gland material, the needle should be inserted in line with the nerves and not across them, corkscrewing, as it were, the suture material, preferably catgut. In this way recovery from slight compression of nerves is soon made.

A low transverse incision in the natural crease in the neck gives the best exposure. The platysma muscle is elevated with the skin. The use of adjustable fork retractors is of advantage in that it saves one assistant. A vertical incision separates the sternohyoid muscles, an incision of the fascia which encloses the sternothyroid muscles allows examination of the gland beneath (Fig. 6). In cases of severe exophthalmic goiter, in substernal goiters, and in large goiters division of the sternohyoid muscles at the upper part of the dissection on one or both sides is indicated for full control of the situation. The first principle of thyroid surgery lies in full exposure, and when the

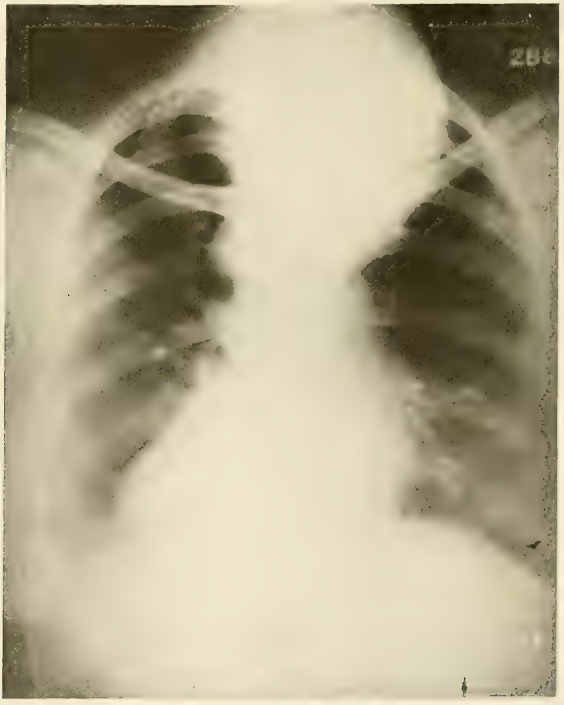

FIG. 7.—SUBSTERNAL GOITER.

goiter is colloid we recommend the equal division of the work on the two lobes, regardless of the fact that one lobe is much larger than the other; the isthmus should also be divided. This is the plan of Mikulicz rather than that of Kocher. The gland along the posterior capsule should be the part retained. Inasmuch as the tissue is not malignant, there is no reason for the careful removal of all of one lobe, leaving similar tissue in the other lobe untouched, as the posterior capsule covers the parathyroids and recurrent laryngeal nerves, which must be retained without injury. This can best be done by section of the front of the gland, removing all that is diseased in bulk and by dividing or usually removing the isthmus. Should simple goiter recur it

can grow to twice the size without external evidence if the isthmus by its division is prevented from dragging the growth forward.

The *x*-ray furnishes valuable aid in showing the size and location of the substernal goiter; the clinician is apt to suspect such growths by the great distention of the veins at the lower part of the neck, especially when they are seen extending to the chest from the region of the neck. Substernal goiters must be separated at the upper

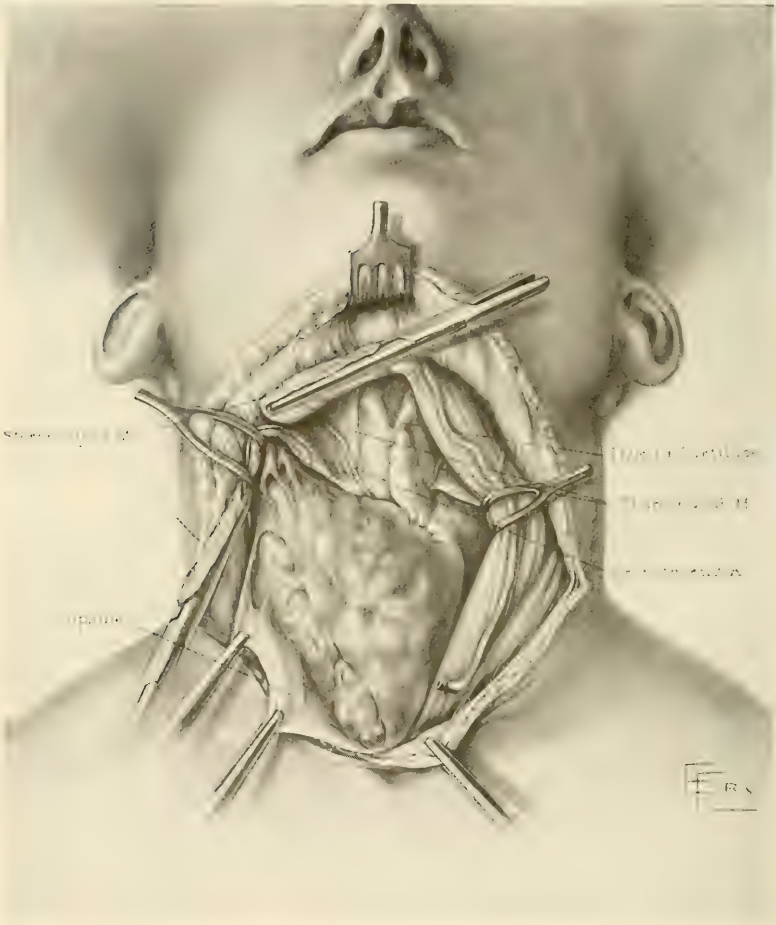

Fig. 8.—Opening Lateral Thyroid Fibrous Capsule.

pole first, and after dividing the isthmus and separating the trachea from the gland on each side, the substernal portion can usually be elevated. Rarely does such a growth extend into the chest, leaving only a small amount of gland projecting into the neck. Often they are too large to bring through the thoracic opening. Fortunately, such glands are always encapsulated, and after grasping the capsule in a forceps and breaking through it the gland may be enucleated with the finger

(Figs. 7, 8). If the base cannot be reached by the finger the gland tissue may be broken up so that it may be spooned out rapidly with a large tablespoon or bladder-stone-forceps until the shell of the tumor collapses and permits of withdrawal. In such cases temporary drainage is indicated; a few hours at most is sufficient to make possible the use

FIG. 9.—SCHEMATIC TRANSPARENCY. SUBCUTANEOUS SUTURE AND TEMPORARY DRAINAGE.

of the Schede blood-clot, since, if the cavity does not collapse with the intrathoracic pressure, the discharge may persist a long time before granulations will close the space. In general, drainage is not indicated in goiter operations if secure control of bleeding is obtained. In cases in which drainage is indicated it is continued for several

hours only. In the closure of the wound the sternohyoid, if divided, is sutured first, next the platysma myoides muscles is sutured to pre-

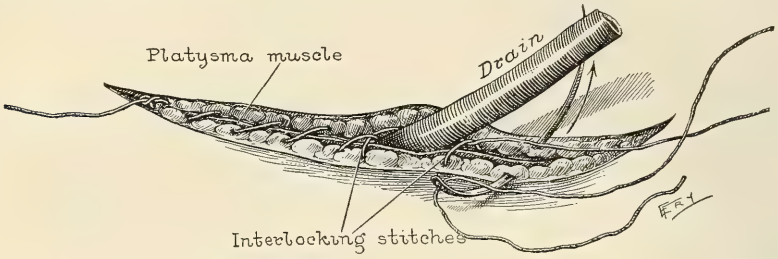

Fig. 10.—Suturing Platysma Muscle; When Suture is Drawn Tightly the Edges of Skin are Approximated.

vent late separation of the cutaneous scar, and then a subcuticular closure is made (Figs. 9, 10).

DANGERS OF OPERATION

The dangers of operation in these cases are due largely to inexperience in surgery of the neck, and especially of the thyroid, but even more to the lack of judgment as to the type of operation to be done in accordance with the severity of the case. We believe that the greatest factor of safety for the patients lies in the thorough knowledge of their general condition on which to base judgment of when and what to do rather than where and how to do it. The better results which have naturally followed the increasing general knowledge of the thyroid have led some surgeons to attribute the dangers of operation to trivial factors, such as development in technic in methods of anesthesia. In cases of simple goiter death is usually due to an accident, such as pulmonary embolism, collapse of the trachea, secondary hemorrhage or pneumonia, and is, therefore, very rare. The mortality following operations on hyperplastic glands, formerly so dangerous by the common methods of procedure, has been reduced to as low as from 2 to 3 per cent. Possibly an unrecognized factor is the present diminution of the former entire number of severe cases with a large number of moderately severe and mild cases, amounting to about 80 per cent., in which the operation has relatively little risk.

COMPLICATIONS

Auricular Fibrillation.—Fibrillation of the heart is occasionally a complication in thyrotoxic goiter; great improvement of this symptom is noted in the patients after operation. True heart block or sinus defects are fortunately seen only occasionally associated with thyrotoxic goiters; these patients have a bad prognosis, and few survive as long as two years.

Injury to the Parathyroids.—Injury to the parathyroids by caus-

ing surgical tetany may result disastrously. Relief in some cases may be obtained, however, by injecting 10 c.c. of lactate of calcium (4 per cent. solution). This treatment tides the patient through possible danger and is repeated as symptoms recur. Those who recover probably will have an injured parathyroid or one which has temporarily lost its circulation; permanent recovery occurs when the remaining gland or glands again functionate. It is quite probable that one good parathyroid is sufficient to prevent tetany. In the future injury to the parathyroid will no doubt be less frequent, since surgeons now realize the value of preserving some part of the thyroid gland on the posterior capsule, and since the operation is now usually bilateral and less radical. Care also will be exercised in protecting the recurrent laryngeal nerves from injury and the consequent voice changes.

Patients who have been operated on for goiter make prompt recoveries; they rarely remain in the hospital more than from five days to a week. The scabbard trachea caused by great bilateral pressure sometimes persists in collapsing at the close of operation; occasionally sutures fastening the sides of the trachea to the lateral tissues at two or three points are required to prevent the collapse.

Recurrence of Disease After Operation.—In at least 10 per cent. of simple and hyperplastic goiters operated on there is some degree of recurrence, and in about half of these a secondary operation is done. Patients who have once had a recurrence retain the tendency for either hyperplasia or new development of adenoma; one-fourth of the patients operated on a second time should have a third operation.

Cretins.—The cretin, failing to develop mentally and physically from lack of thyroid, is often subjected to surgical transplantation of thyroid in an effort to secure permanent relief. We have transplanted the glands into various regions many times, but relief was obtained only while the tissue was being absorbed. Now that we have in thyroxin a stable medication for the gland secretion I believe that more can be done by its use than by surgery.

Myxedema.—In myxedema the metabolic rate is usually from 20 to 40 points below normal from the rate it is possible to determine the exact degree of the disease, which is far more common than is generally supposed. Only a relatively small number of cases are the result of operative procedures. Some type of thyroiditis destroys the gland function. The cases following operative procedures are usually recognized, as are many of the others, but in the latter type should thyroid medication fail to give benefit, an effort is made to explain the condition on other grounds. I wish to call attention to the fact that some persons requiring thyroxin are unable to absorb it in the usual way and it must be given hypodermically. Normally about 7 mg. of thyroid secretion is supplied in the body. From 5 to 7 mg. of thyroxin, the active principle of the thyroid gland, can be given in cases of myxedema with most marvelous results; within a few days the change in the body chemistry results in immediate reduction of the edema. Rarely a patient with exophthalmic goiter, after living many

years with the condition, develops a state of marked myxedema. That the life of a patient suffering from myxedema may be greatly prolonged is shown by Murray's report of a patient thus afflicted whose normal health was maintained for twenty-eight years by thyroid medication, mostly hypodermic administration.

In closing this brief review of the surgical treatment of goiter I wish to express my appreciation of that master surgeon, the late Theodor Kocher, whose research investigation, pathologic knowledge, and surgical genius laid the foundation of the study of the thyroid for modern students of medicine.

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CHAPTER XXVIII

RECENT ADVANCES IN OUR KNOWLEDGE OF PATHOLOGY OF GOITER

By Louis B. Wilson, M. D.

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In addition to the summary given in Chapter CXII, Volume VI, the following is a summary of the more recent advances in our knowledge of the pathology of the thyroid gland:

1. **Compensatory Hyperplasia.**—Halsted[2] has recently reported failure to repeat his classic experiments on the production of a compensatory hyperplasia in the remaining portion of a dog's thyroid after partial thyroidectomy, and now thinks that his former results were due to some infection or error in technic.

2. **Experimental Thyroid Hyperplasia.**—Cannon[1] has been able to produce experimentally in the cat many of the symptoms of hyperplastic toxic goiter by crossed physiologic stimulation of the cervical sympathetic nerve through its anastomosis with fibers of the phrenic nerve.

3. **Etiology of Endemic Goiter.**—McCarrison,[3] in an elaborate series of experiments, has succeeded in producing symptoms of endemic goiter by the administration of "goiterous" waters, of filtrates from the same, and of pure waters contaminated with feces of goiterous animals.

4. **Pathology of Thyroid in Goiter.**—My detailed study of the principal changes found in 1208 thyroids[4] removed from patients diagnosed clinically as having exophthalmic goiter and of 2356 thyroids[5] removed from patients diagnosed clinically as having simple goiter warrants the following general statements:

(*a*) The pathology of the thyroid in true exophthalmic goiter is essentially a primary parenchymatous hypertrophy and hyperplasia, that is, an increased amount of functionating parenchyma associated with an increased absorption. The process is an acute one.

(*b*) The pathology of atoxic simple goiter is marked essentially by atrophic parenchyma, decreased function, and decreased absorption. The process is a chronic one. It is parallel in stages of development and regression with similar stages of development and regression of symptoms.

(*c*) The pathology of the thyroid in toxic non-exophthalmic goiter[6] in cases most resembling ordinary exophthalmic goiter is probably one of increased parenchyma through regenerative processes in atrophic parenchyma, or the formation of new parenchyma of fetal type with an increase in each instance of secretory activity and absorption. The new parenchyma of fetal type may be diffuse or indefinitely walled

adenomas. The process is a chronic one. Toxic non-exophthalmic goiter cases, which clinically do not so much resemble exophthalmic

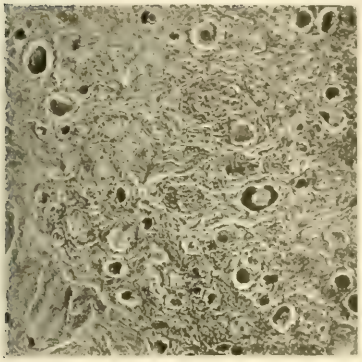

FIG. 11.

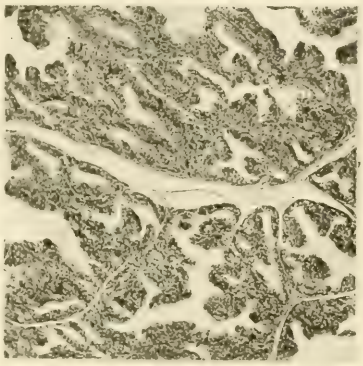

FIG. 12.

FIG. 11.—(CASE A–107215.) FEMALE TWENTY-FOUR YEARS OF AGE. ENLARGED THYROID ELEVEN MONTHS, AND SYMPTOMS OF HYPERTHYROIDISM FIVE MONTHS BEFORE SYMPATHECTOMY.

Longitudinal section of superior cervical sympathetic ganglion, showing the total number of cells not apparently reduced, a few only hyperchromatic, and many in varying stages of granular degeneration. × 120. Silver impregnation.

FIG. 12.—(CASE A–107215.) SECTION OF THYROID REMOVED FOUR MONTHS AFTER REMOVAL OF SYMPATHETIC GANGLION SHOWN IN FIG. 13, SHOWING ACTIVE PARENCHYMATOUS HYPERTROPHY AND HYPERPLASIA, TYPE B. × 60. HEMATOXYLIN-EOSIN.

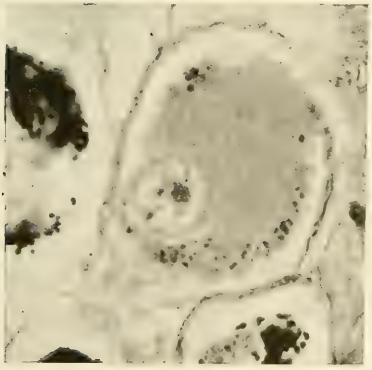

FIG. 13.

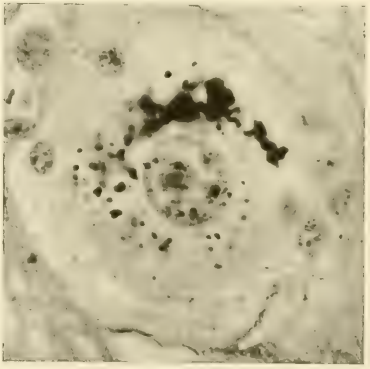

FIG. 14.

FIG. 13.—(CASE A–49068.) GANGLION CELL SHOWING ADVANCED CHROMATOLYSIS WITH SLIGHT LIPOCHROME HYPERPIGMENTATION IN PERIPHERY AROUND IT, AND REMNANTS OF OTHER GANGLION CELLS WITH ADVANCED GRANULAR DEGENERATION NEARBY. × 600.

Silver impregnation.

FIG. 14.—(CASE A–129966.) GANGLION CELL WITH GRANULAR DEGENERATION OF THE PROTOPLASM AND NUCLEUS IN EARLY STAGE OF KARYOLYSIS. × 600.

Silver impregnation.

goiter—that is, those in which the symptoms are more of the cardiovascular type in their pathology—much more closely resemble cases of

simple goiter. A large number of them are apparently of the colloid goiter type. Many of these have single or multiple adenomas in the thyroid.

(*d*) The above pathologic evidence points to a constant relative association of increased secretion and increased absorption from the thyroid proportional to the degree of toxicity on the part of the patient.

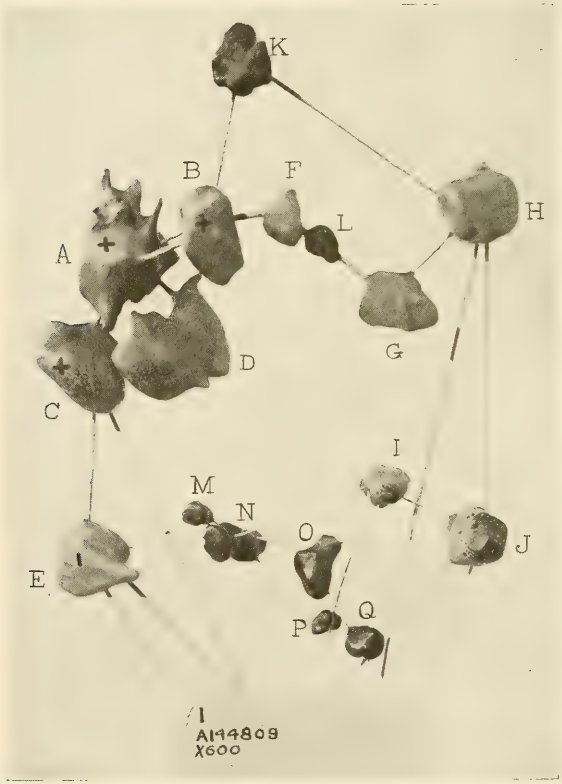

FIG. 15.—(CASE A–144809.) BORN RECONSTRUCTION IN WAX OF A GROUP OF GANGLION CELLS OF THE LEFT SUPERIOR CERVICAL SYMPATHETIC GANGLION OF A FEMALE THIRTY YEARS OF AGE WHO HAD HAD SEVERE EXOPHTHALMIC GOITER FOR EIGHT MONTHS.

Of the seventeen cells shown, two, *A* and *B*, show apparently normal protoplasm and nuclei, though they are hypertrophied. One other, *C*, near them, is markedly hypertrophied, and though its nucleus is normal, it shows beginning pigmentation. Another, *D*, in the immediate vicinity, is markedly hypertrophied, shows beginning pigmentation, and its nucleus has completely disappeared. One, *E*, which is normal in size, shows beginning degeneration of the nucleus and no pigmentation. Three others, *F*, *G*, and *H*, though showing no pigmentation, show complete destruction of the nucleus. Two, *I* and *J*, show advanced pigmentation with destruction of the nucleus, and seven, *K*, *L*, *M*, *N*, *O*, *P*, and *Q*, are reduced to atrophic masses of solid pigment.

We have as yet no absolute proof that such secretion and absorption is the cause of the symptoms rather than co-ordinate with them, but the evidence presented strongly points to that conclusion.

5. **Muscular Involvement in Goiter.**—(*a*) **Heart.**—In a large series of autopsies I have shown[7] that the gross evidence of myocardial change is present in a higher percentage of cases of goiter than in that

of any other systemic disease except those in which the chief clinical diagnosis related directly to heart lesions. The microscopic evidence of myocardial damage is even more inclusive, very extensive fatty degeneration of fibers being present in practically every case of exophthalmic goiter coming to autopsy.

(*b*) **Skeletal Muscles.**—Similar extensive changes are found in the skeletal muscles. These are most marked in the quadriceps extensors, the intercostals, the sternomastoids, and the recti muscles of the eye.

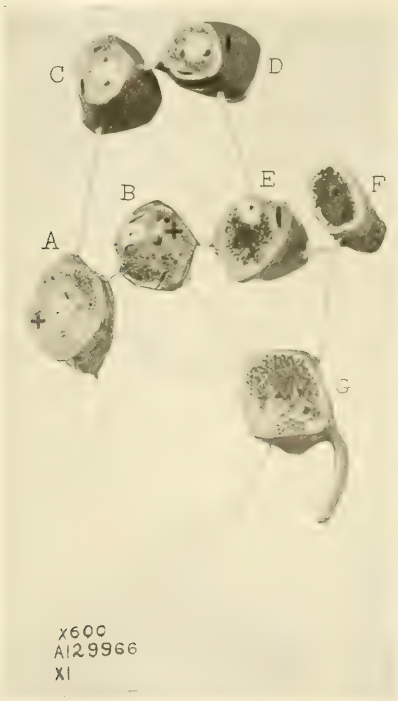

Fig. 16.—(Case A–129966.) Born Reconstruction in Wax of a Group of Ganglion Cells in the Left Superior Cervical Sympathetic Ganglion of a Female Thirty Years of Age Who Had Had Severe Symptoms of Exophthalmic Goiter for a Year.

An examination of the sections from this ganglion showed in most areas a marked atrophy of the ganglion cells. The group selected for reconstruction is from an area in which the cells are hypertrophied. In the model each cell is bisected and on the cut surface are indicated the pigmentation and appearance of nuclei; the latter is also indicated by arbitrary signs. A photograph has been taken of the model with the loose portion of each cell removed. Of the seven cells shown, none is normal, though two, *A* and *B*, show nuclei without material degeneration. In three others, *C*, *D*, and *E*, degeneration has begun in the nuclei, and in two, *F* and *G*, the nuclei have completely disappeared. All the cells are markedly pigmented.

6. **Ganglion Cell Changes in Exophthalmic Goiter.**—Durante and I[8,9,10] have shown that definite histologic changes occur in the cervical sympathetic ganglia in exophthalmic goiter. These changes consist of various stages of degeneration, namely, (*a*) hyperchromatization, (*b*) hyperpigmentation, (*c*) chromatolysis, and (*d*) atrophy or granular degeneration of the nerve-cells. All of these are but successive steps in degeneration, which if uninterrupted proceed to the complete

destruction of the ganglion cells affected. Not all of the ganglion cells in any of the ganglia examined were so completely destroyed as to render improbable their return to normal under favorable conditions. Accompanying the more advanced changes in the ganglion cells are similar degenerative changes in the nerve-fibers, and an increase of connective tissue throughout the ganglion, but especially in the outer and middle coats of the vessels and in the periganglionic tissue. The degree of hyperpigmentation, the amount of granular degeneration, the atrophy, and the reduction in the number of ganglion cells are approximately in direct relation to the continuation and subsequent remission of the symptoms of hyperthyroidism. The perivascular connective tissue and the connective-tissue stroma generally through the ganglion are increased in direct ratio to the time during which the symptoms of hyperthyroidism had continued. These changes in the ganglion cells are quite distinct from those due to senility or to other prolonged wasting diseases. They are shown in Figs. 11–16.

It is possible that these changes in the ganglion cells may result directly from the generally toxic condition in exophthalmic goiter. They probably may be best explained on the hypothesis of a specific primary infection of the ganglion itself.

Experimentally I[11] have been able by direct inoculations into the cervical sympathetic ganglia of goats to produce histologic pictures within the ganglia and in the thyroid which resemble those found in exophthalmic goiter in man. While these experiments are few and far from conclusive, they support the suggestion that in exophthalmic goiter the thyroid receives its stimulus to overfunction through its nerve supply and as a result of overstimulation of the cervical sympathetic ganglia.

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CHAPTER XXIX

THE CHEMICAL NATURE OF THE THYROID SECRETION

By E. C. Kendall, Ph. D.,
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In 1895 Baumann drew the attention of chemists to the thyroid by discovering that the gland normally contains iodin. Shortly after this discovery a large amount of work was carried out with the thyroid substance in an endeavor to isolate the compound containing iodin, and Baumann himself was able to separate a fraction of the glandular material containing 9 per cent. iodin. Since that time many other attempts to isolate the substance have been carried out, but until 1914 no single compound in pure crystalline form, possessing physiologic activity, had been isolated from the thyroid. This work, carried on in the Mayo Foundation, has involved the treatment of $3\frac{1}{4}$ tons of fresh thyroid glands. From this amount of material about 35 grams, slightly more than 1 ounce, of the iodin-containing compound has been isolated in pure crystalline form.

Since 1895, when the problem of the relation between iodin and thyroid activity was raised, investigators have championed both the iodin-containing compound and the non-iodin-containing portion of the gland in their attempts to prove the physiologically active substance. The isolation of the iodin-containing compound in pure form, which has been named "thyroxin," now permits a solution of this problem. It has been definitely and quantitatively shown that thyroxin is capable of producing all the symptoms of hyperthyroidism and relieving all the symptoms of myxedema just as completely as does desiccated thyroid. The substance has, furthermore, been identified chemically, and the reactive groups within the molecule have been determined. This, in turn, has permitted the synthesis of the substance, so that now from a chemical standpoint the thyroid secretion is as well known as are the clinical syndromes involved in hypothyroidism and hyperthyroidism and the histologic changes which occur in the gland.

It was, therefore, of great interest to determine the chemical nature of this iodin-containing compound which occurs in the thyroid and is so fundamentally involved in normal physiology. Analysis has shown that it contains an indol group with the iodins undoubtedly attached to the benzene ring, and that on the carbon atom adjacent to the imino group of the indol ring there is an oxygen atom (Fig. 17). From its physiologic activity it appeared desirable to emphasize the presence of the oxy-indol nucleus, and it appeared equally desirable not to emphasize the presence of iodin. The substance was, therefore, named

"thyro-oxy-indol," which has been shortened to "thyroxin" for every-day reference to the substance.

The injection of pure thyroxin is followed by a very definite and marked physiologic response. When the hydrogen on the imino has been replaced with acetyl the substance loses its physiologic activity and the injection of the substance is without demonstrable effect. Investigation of the acetyl showed that, in alkaline solution, the indol

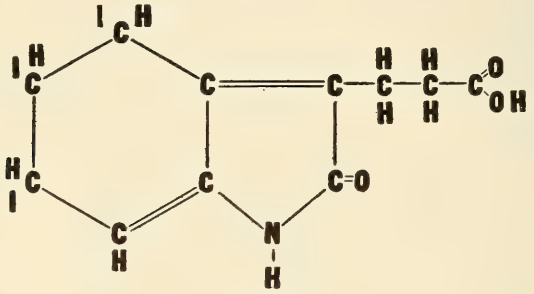

Fig. 17.

form of the compound no longer exists, but that there is hydrolysis of the CO and NH groups, resulting in the opening of the ring and the formation of COOH and NH_2 (Fig. 18). Further investigation showed that thyroxin behaves in this same way, and that it exists within the body not in the closed ring form such as is present in indol, but in COOH NH_2 form. The ability of the indol ring thus to open furnished the first concrete conception of how the substance behaves chemically

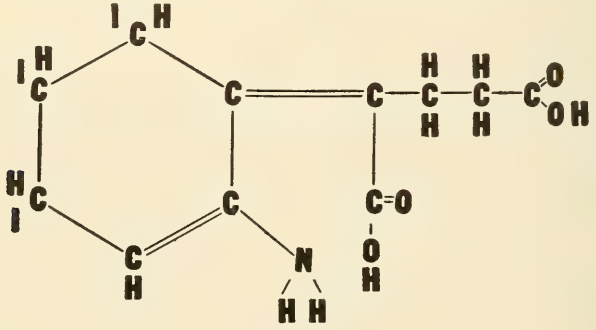

Fig 18.

within the body. The fact that both thyroxin and the acetyl derivatives exist in open form suggests that the reason for inactivity of the acetyl is because of interference with the chemical reaction associated with the NH_2 group of thyroxin. The fact is at once apparent that the open and closed forms of thyroxin bear to each other the same relation as does creatin to creatinin, and that the same relation exists between amino-acids and the form in which amino-acids are united in protein. Establishing these active groups emphasizes the importance of the

CO—NH and COOH NH_2 groups within the body, which appear to be necessary structures for the carrying out of the chemical changes leading to the production of energy.

Patients with complete atrophy of the thyroid have basal metabolic rates approximately 40 per cent. below normal. It has been shown that administration of thyroxin alone can bring back and maintain the normal metabolic rate in such patients. But in complete atrophy of the thyroid the complete or nearly complete absence of thyroxin may be assumed. The question arises as to what maintains energy output from 100 per cent. below normal, which would be death, up to 40 per cent. below normal, the point to which basal metabolism sinks in the absence of thyroxin. May it not be the other chemical substances in the body possessing the same grouping that occurs in thyroxin? These are amino-acids and proteins, creatin and creatinin, and a few other less well-known compounds. It seems probable that on the administration of thyroxin a reaction which has been carried on within the body by other compounds is merely increased in rate, but that there is no difference or disturbance of the reactions that have been going on.

In regard to the relation of iodin to the activity of thyroxin, the presence of iodin in the compound must exert some influence, and it seems not improbable that the presence of iodin renders the active groups more reactive. In the absence of iodin it would take a greater working pressure to bring about its reaction. The substitution of the iodin by hydrogen or chlorin or bromin would undoubtedly be followed by an alteration in the degree of reactivity of the substance, but its gross chemical nature and properties would not be altered thereby. That the iodin breaks off from the molecule and is used as iodin *per se* seems impossible, because Plummer has shown that this substance functions for as long as from fifteen to twenty-one days after being administered, and that it acts as a true catalyst, being used over and over, hour after hour, without destruction except at a very low rate. Some idea of the rate at which thyroxin is destroyed is furnished by the effect of administering thyroxin to myxedema patients. A large number of patients have now shown that from 1 to $1\frac{1}{2}$ milligrams of thyroxin administered daily is entirely adequate to maintain them in a normal condition. The administration of more produces hyperthyroid symptoms. Thyroxin is very slow to begin functioning, but it continues active for about three weeks. It is finally removed from the body either by actual destruction or by slow loss in an undestroyed form. Our knowledge of other catalytic agents shows that poisoning of catalysts is common if not universal, so that its slow destruction is to be expected.

The exact chemical reactions involved when this substance functions are still unknown, but that the substance possesses the formula as shown above is established by the ultimate chemical analysis of its derivatives. That the active groups present in thyroxin are a necessary mechanism for the production of energy within the body seems highly probable, and it is of great interest and significance that there exists a close analogy between this substance, whose exact effect on metabolism we

know, and other substances, creatin, creatinin, amino-acids, and proteins, which are also intimately associated with reactions occurring within the animal organism. Are these substances also concerned in the maintenance of the basal metabolic rate?

That the administration of desiccated thyroid sometimes has a remarkable influence on growth is shown in the case reported by Gibson,[6] in which a lad aged seventeen grew 7 inches in six months and was enabled to enter the British Military Academy. Evidence that thyroxin is the active constituent of the thyroid is shown by its influence on growth; in some cases it has produced extraordinary results. For example, a girl aged ten was seen at the Mayo Clinic January 4, 1915. She was a cretin only 37 inches high and weighed only 37 pounds. In four and one-half years under no medication but thyroxin (0.4 to 0.8 mg. a day) her height increased from 37 to 52.5 inches (more than 33 per cent.), and her weight from 37 to 65 pounds (almost 80 per cent.).

Still more encouraging, she has become bright and active, is attending school, and is restored as nearly as possible to normal, considering the late time in her life when this medication was started.

She has received no thyroid substance except thyroxin during this time, and, therefore, all the improvement, both physical and mental, is due to this single substance. Moreover, her skin has become soft and moist; her hair, which had been coarse and thin, is thicker, softer, and much longer, and her mentality has wonderfully improved.

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CHAPTER XXX

THE ADRENAL GLANDS

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A few anatomic facts are of prime importance with regard to the possible surgery of the adrenal glands. The adrenal tissue is placed bilaterally in two glands, thus affording the possibility of removing one gland and leaving the other intact. In addition to this the cortex and the medulla of each gland are embryologically and anatomically separate, but very closely related. The cortex and medulla both present marked characteristic histologic arrangement. The cells of the medulla form the major portion of the so-called chromaffin tissue. The sympathetic nervous system is very intimately connected with this portion of the gland. There are no valves interposed between the venules draining the gland and the heart.

Physiologically the glands also seem to be dual in nature. It has long been known that from the medulla a definite substance, called variously adrenalin, adrenin, or epinephrin (the Greek equivalent of the Latin suprarenal), can be extracted; this has a very interesting and characteristic pharmacologic action. In general, it may be said that this action is the same as that of stimulation of the sympathetic nervous system. If stimulation of the sympathetic nerves of an organ produces excitation of that organ, adrenalin will produce excitation; if, on the other hand, the stimulation produces inhibition, adrenalin will do the same. The action of adrenalin, on the whole, is peripheral in character, and, for want of more exact knowledge, it is said to act on the nerve-endings. The physiologic purpose of adrenalin is not known. Certainly its action as determined by pharmacologic experiments is not duplicated in the body, because the amount produced by the normal gland is too small. It has been shown quite conclusively that adrenalin is actively secreted by the medulla, and even the amount which the gland secretes on stimulation produces many reactions which the body employs in a physiologic emergency. However, there is evidence to justify the belief that such emergency can only be limited and may not be of great importance.

Little is known with regard to the physiology of the cortex; its most noticeable feature is the high characteristic lipoid content. The size of the cortex and the amount of lipoid undergo variations under different conditions, for instance, they both increase during pregnancy. Not only the amount of lipoid but probably also its character varies with different pathologic conditions. Whether or not the cortex plays any part in the production of adrenalin is doubtful.

The adrenals are remarkably free from demonstrable disease. Probably tuberculosis is the best known pathologic condition of the adrenals; it has been fully described by Addison in his classic work on the adrenals. Tumors also occur in the adrenals; the most important is the characteristic carcinoma. Small adenomas are often noted, but seem to be of little importance. Hemorrhages in the substances of the glands have been described as important factors in causing death. I have been able to produce these hemorrhagic lesions in the adrenals experimentally by two different methods. They may often be produced by the administration of diphtheria toxin, intravenous injection of peptones, and other toxic substances. They seem to depend on the direct action of some toxin, and this probably explains why they occur in such diseases as diphtheria and scarlet fever. They may also be produced by the administration of a drug which will produce a prolonged convulsion. In such instances it is possible, since the veins have no valves, that the hemorrhages are due to the increased venous pressure. While the possibility of either hyperfunction or hypofunction of the glands must be admitted, it is equally true that there are not enough physiologic or clinical data extant to justify the diagnosis of either of these conditions, exclusive of gross anatomic pathologic changes.

Important, although limited, advances with regard to our knowledge of the adrenals have been made by their removal from animals. I have removed the adrenals from six species of animals—the dog, cat, rabbit, guinea-pig, rat, and striped gopher (C. tridecemlineatus)—in a total of about 300 experiments. The adrenals may be removed either by a transabdominal section or an incision in the loin. I have removed them extraperitoneally through the loin. One adrenal may be removed from any of the species enumerated without producing demonstrable effect. If complications or death occurs, it is always due to hemorrhage, injury to nerves or ganglia, the anesthetic, etc. Usually the remaining adrenal hypertrophies; the hypertrophy may be confined to the cortex, but I have occasionally noted it in the medulla also. As a matter of fact, if only one-third of one gland is left with blood-supply intact it will hypertrophy and the animal will live. Puppies from which I have removed all but approximately one-sixth of the adrenal tissue have developed normally. The removal of both adrenals always produces death in the dog, the cat, and the guinea-pig; about half the rabbits and rats die, and very rarely a gopher, probably because the rodents have accessory adrenal tissue. I confess, however, that I was quite unable to find any accessory adrenal tissue in many of the gophers from which the adrenals had been removed many months previously.

The clinical symptoms following total removal of the adrenals are characteristic. In the dog and cat they are as follows: The animal recovers from the immediate effects of the operation and remains seemingly in a perfectly normal condition for from twenty-four hours to nine days after operation, depending on several known and probably many unknown factors; for instance, the length of the operation and the anesthetic are important. If the glands are removed at a single

operation, death occurs much sooner than if they are removed at separate operations with a few weeks' interval, probably because the total removal at a single operation requires longer anesthesia, and there is more hemorrhage. Keeping the animal quiet and warm will greatly prolong life. I have been able to produce the onset of the fatal symptoms, changing a seemingly normal dog into a moribund condition within two hours by a few minutes of intensive exercise or exposure to cold. Usually the first noticeable symptoms ushering in the fatal onset are an increase in the pulse-rate and a slight increase in the temperature. Often these symptoms are absent, however, and there is an onset of definite and usually marked muscular weakness, a subnormal temperature, a slow pulse, and falling blood-pressure. The muscular weakness sometimes develops slowly, but usually it comes on within a short time. The temperature drops rapidly, despite methods used to maintain it. An animal with a normal temperature of from 99° to 100° F. may have a temperature of 94° F. before death. Keeping the animal at body temperature delays but does not prevent the fatal outcome. The action of the heart may become extremely slow; I have noted it beating only 12 times a minute. Large doses of atropin will temporarily increase the rate; section of the vagus nerves also increases the rate and may restore it almost to normal; it usually decreases again before death, but does not drop so low as before the nerves were cut. The blood-pressure progressively falls, sometimes to as low as 20 mm. before death. Increasing the blood-pressure by drugs or injections may delay but does not prevent death. As the blood-pressure falls other symptoms associated with it, such as anuria, appear. Muscular weakness, decreased blood-pressure, and subnormal temperature are usually noted so close together that it is impossible to designate any one of them as primary. There may be other minor symptoms, such as loss of appetite, diarrhea, and a characteristic odor. These are present only in the animals in which the condition develops slowly. In view of the seeming relationship of the sympathetic nervous system to the adrenals it is interesting to note that the reaction of the eye to light usually remains normal until the animal is moribund. It also does not seem that the adrenals can be an important factor in the acceleration of the heart, because increase in the heart rate after adrenalectomy will follow exercise until the animal is too weak to exert itself. It should also be noted that a dog exhibits all the bodily reactions to fear and rage after removal of the adrenals.

The findings at necropsy after adrenalectomy are also characteristic. The most important of these is congestion of all the organs, particularly of the liver and pancreas; the latter is of a mulberry color, which I have never seen in any other condition. The blood-vessels of the gland stand out so prominently that the supply to every little lobule is plainly visible. The bladder is empty and tightly contracted; the gall-bladder is also usually empty. The stomach and duodenum contain small punched-out ulcers or large areas of congestion and erosion of the mucosa. The large intestine is always markedly congested. His-

tologically all the organs show congestion, and frequently the liver and spleen show pigmentation.

The cause of death following adrenalectomy is not known. The characteristic changes noted at necropsy suggest that before death a very toxic condition exists. The most plausible hypothesis seems to be that the adrenals produce a secretion which is necessary for some phase of metabolism and, when this is lacking, a fatal toxic condition ensues due to the incomplete metabolism. It seems highly probable that the cortex is wholly responsible for this function. Some of the results of adrenalectomy are undoubtedly due to the injury of the sympathetic ganglia, but death is certainly not due to such trauma.

It is interesting to note that experimentally a condition simulating Addison's disease has not been produced. The relation of pigmentation to disease of the adrenals is unsolved. I have noted pigmentation in some of the gophers in which the adrenals had been removed some months previously, but I was not able to establish any causal relationship.

The surgery of the adrenal in man seems to have been limited to the removal of tumors of the gland. There is a clinical condition in which the development of a tumor of the adrenal is accompanied by a marked change in the strength, growth, and development of secondary sexual characteristics of the individual. The removal of the tumor in suitable cases of this type seems to have produced very beneficial results. In view of our present knowledge of the adrenals, the surgeon seems to be justified in removing one of the glands only when a tumor has developed in it. The onset of tuberculosis of the gland seems to be too insidious and bilateral in character to allow a diagnosis to be made at a time when the diseased portion could still be eradicated and the remaining tissue still hypertrophy.

Experimental surgery has taught a few definite facts with regard to the adrenals which may be of value in the possible future development of the practical surgery of the glands: Technically adrenalectomy is feasible. One gland may be removed with perfect safety if the other gland is normal. Total removal of adrenal tissue is always fatal.

CHAPTER XXXI

SURGERY OF THE HYPOPHYSIS

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Rochester, Minn.

The clinical significance of the hypophysis, as an endocrine gland, has attracted attention from the physiologic standpoint, and, while surgical intervention has afforded relief in the treatment of disorders of the gland, it has not given the relief that may be expected.

I shall not discuss in detail the anatomy and physiology of the hypophysis, since these points have been ably covered by Lewis and Kanavel. I wish to emphasize, however, that the hypophysis is an important gland in the endocrine chain and that life depends on its function. While cases have been reported in which the gland was completely removed with continuation of life, it is doubtful whether all the gland was removed. The experimental work of Paulesco and Cushing proves that the secretions of the gland are essential to life, and that its complete removal results in death within two or three days in adult animals and within ten or eleven days in younger animals. The anterior lobe,[10] which comes from Rathke's pouch, is related to the metabolic function of the body in that hypersecretion produces acromegalia (gigantism) and hyposecretion produces Fröhlich's syndrome, or infantilism.[4] The posterior lobe has a vasomotor influence in addition to the stimulation of smooth muscles, and the pars intermedia, which is composed of epithelial tissue and neuroglia, is believed by some observers to influence the metabolic function of the body, although its exact function is undetermined.

Besides a simple hypertrophy of the gland, various types of tumor are found, the nature of which depends on the origin, whether in the anterior or the posterior lobe. Inasmuch as the anterior lobe is of epithelial origin, adenomas, sarcomas, and some of the rarer epithelial tumors occur in this region, and as the posterior lobe arises from neurogliar tissue, the gliomas, fibromas, carcinomas, etc., are found there. The cystic type of tumor, which is generally lined with epithelial membrane, occurs most frequently in the pars intermedia. Hypophyseal tumors vary in size and position, depending on their development. Simple hypertrophies and adenomas have a tendency to enlarge the sella without marked erosion, while tumors of the posterior lobe very often enlarge the sella and erode the posterior clinoid process. Carcinoma and sarcoma have a marked tendency to produce an irregular erosion in the floor of the sella. The suprasellar extension, which pro-

duces pressure on the optic peduncle and commissure, forming various hemianopsias, may occur in any of the pathologic conditions of the hypophysis, but rarely in simple hypertrophies.

Patients with hypophyseal diseases complain of one of three groups of symptoms, metabolic, ocular, or regional,[6],[12] the latter consisting of disturbance of smell and taste, or mental deterioration. Marie in 1889 described the disease known as acromegalia. It is easily recognized by such clinical factors as dull facial expression, enlargement of the head, broad, large nose, thick lips, very large protuberant tongue, large lower jaw, separation of the teeth, and large bulky hands and feet. The change of voice is marked; the tone becomes heavy and coarse. Miege believes that gigantism is nothing more than the development of acromegalia in the youth. The disease may assume a benign form and last for perhaps fifty years, with but few symptoms. A chronic form may last from eight to thirty years, and a malignant form with a relatively short clinical course, from three to four years.

The symptoms produced by hyposecretion were described by Fröhlich in 1901 (dystrophia adiposogenitalis), a condition which is characterized in youth by rapid increase in weight, due to accumulation of fat about the abdomen and genitalia, lack of sexual development, absence of axillary and pubic hair, a feminine voice, and a high tolerance of sugar. The same condition develops in the adult and is characterized by loss of sexual power and atrophy of the testicles, loss of axillary and pubic hair, a soft, pasty, pale skin, a subnormal metabolic rate, and mental deterioration. While these patients do not have delusions or hallucinations, they do not realize their responsibilities and have a tendency to become foolish.

The ocular disturbances consist of bitemporal hemianopsias, that is, patients complain of inability to see objects unless brought directly in front of them (Figs. 19–22). As the disease progresses the field is not only narrowed, but the patient is very apt to lose the entire vision of one eye and have a narrowed field in the other. Again, patients may be free from metabolic or ocular disturbances, but complain of disturbance in smell and taste, of headache and pain, and a loss of memory. If the lesion is confined to the anterior lobe of the hypophysis the patient will complain of metabolic disturbance only, while if the lesion extends posteriorly or upward, it is not uncommon for the patient to present symptoms referable to more than one group.[8],[29]

x-RAY EXAMINATION

Examination by means of the *x*-ray is of great value in suggesting the type of lesion (Figs. 23–25), as stereoscopic plates show quite distinctly the enlargement and erosion of the sella. It has been demonstrated at operation that a simple enlargement of the sella is apt to be associated with a benign lesion, while a large eroded sella is more apt to contain carcinoma or sarcoma. Palliative relief may be obtained by partial removal of a malignant lesion, but the results are not so satisfactory as in benign lesions.

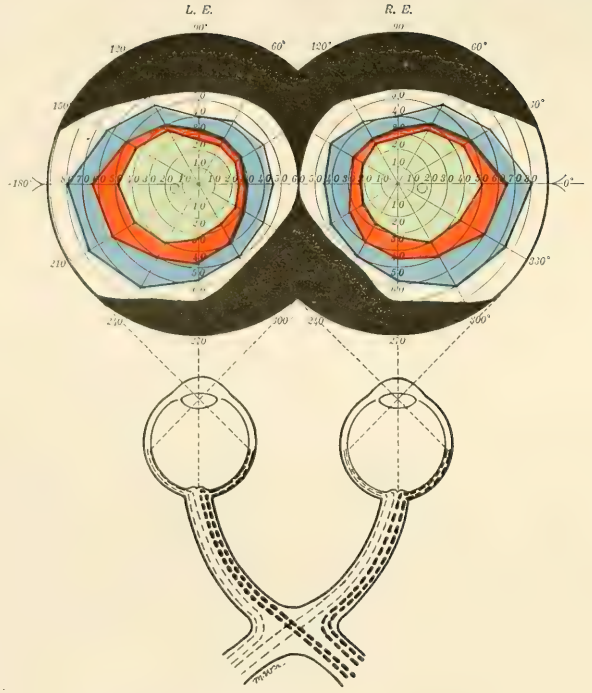

Fig. 19.—Normal Optic Tracts and Fields.

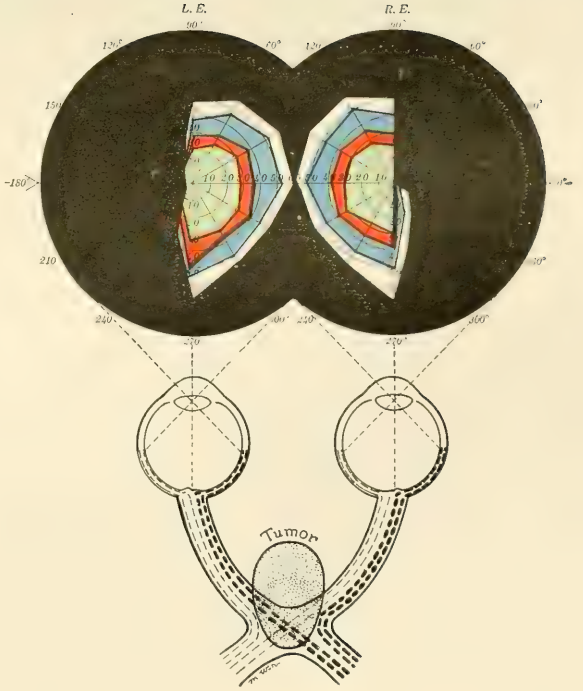

Fig. 20.—Bitemporal Hemianopsia Due to a Pituitary Tumor Situated in the Fork of the Optic Peduncles.

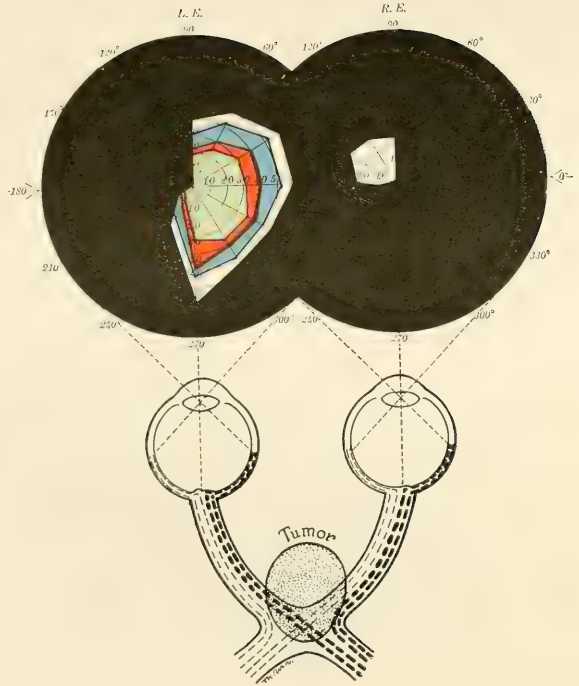

Fig. 21.—Bitemporal Hemianopsia with a Constriction of the Right Nasal Field Due to a Pituitary Tumor Situated in the Fork of the Optic Peduncles, but which has Extended to the Right Sufficiently to Catch Most of the Nasal Fibers.

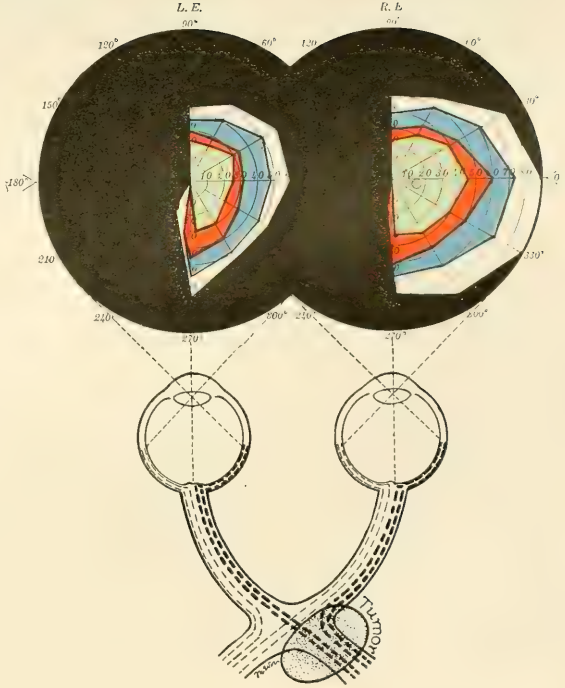

Fig. 22.—Left Homonymous Hemianopsia Due to an Involvement of the Right Optic Tract Posterior to the Optic Commissure.

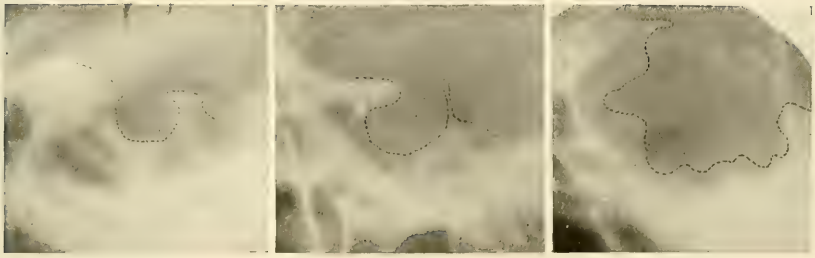

Fig 23. Fig. 24. Fig 25.

Fig. 23.—(Case 207279). Normal Sella Containing a Fibroma Producing Blindness in the Right Eye and a Loss of the Left Temporal Field.

Fig. 24.—(Case 219123). Enlarged Sella Without Erosion, Containing a Malignant Tumor Producing a Blindness in the Left Eye with a Loss of Vision in the Right Temporal Field.

Fig 25.—(Case 253290). Enlarged and Eroded Sella Containing a Malignant Tumor Producing Bitemporal Hemianopsia and Associated with Marked Symptoms of Acromegaly.

SURGICAL TREATMENT

Because of the inaccessibility to the sella turcica, surgical treatment of hypophyseal diseases has been practically limited to patients suffering with ocular disturbances (Fig. 26). The sella is approached from

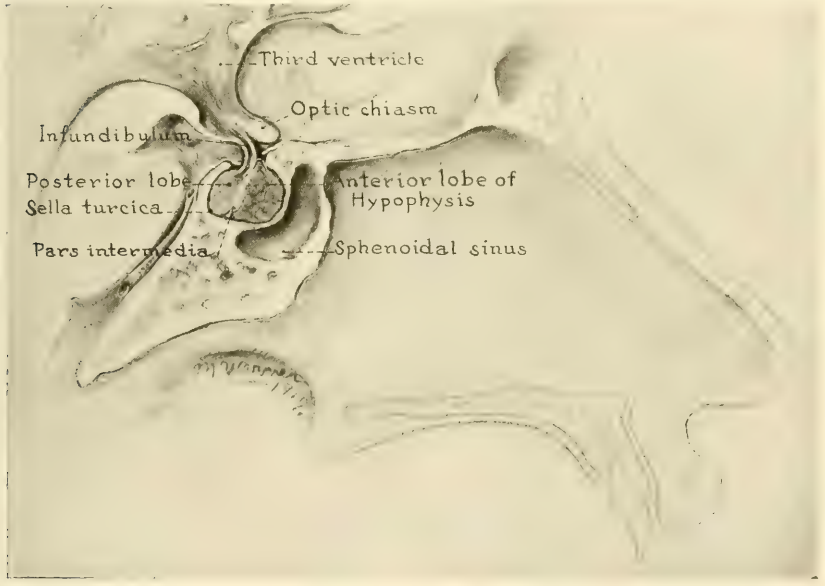

Fig. 26.—Median Section of Pituitary Gland with Its Normal Anatomic Relations.

in front and below by the extracranial transsphenoidal method, and from above and the side by the intracranial, extradural, and intradural methods.

The earlier operations were attended with considerable trauma to the frontal lobe, and the extracranial method has been used more generally, because surgeons believed it to be attended with less risk than the intracranial method.

The transsphenoidal approach has been modified by a number of operators as supranasal, infranasal, and transnasal. This approach is not always satisfactory since it is attended with excessive bleeding, provides only a limited operative field, and, while a subsellar decompres-

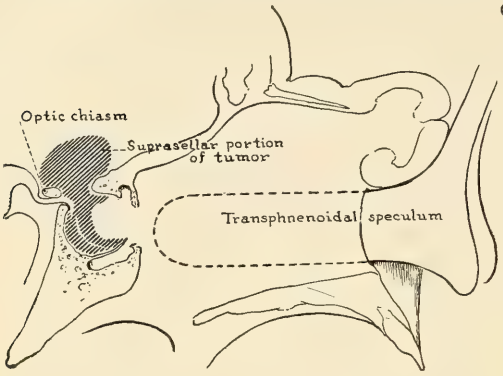

FIG. 27.—THE TRANSSPHENOIDAL APPROACH, SIMILAR TO THAT DESCRIBED BY CUSHING.

FIG. 28.—THE RESULTS OF THE TRANSSPHENOIDAL PROCEDURE, CALLING ATTENTION TO THE PARTIAL REMOVAL AND THE DROPPING DOWN OF THE SUPRASELLAR GROWTH.

sion with a partial hypophysectomy can be done, it is impossible to remove a suprasellar tumor; moreover, there is danger of intracranial infection (Figs. 27, 28).

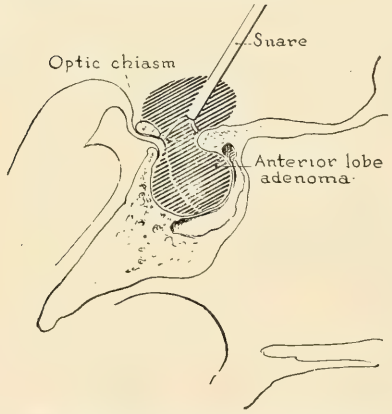

FIG. 29.—REMOVAL OF THE SUPRASELLAR GROWTH PRIOR TO THE RESECTION OF THE INTRASELLAR TUMOR.

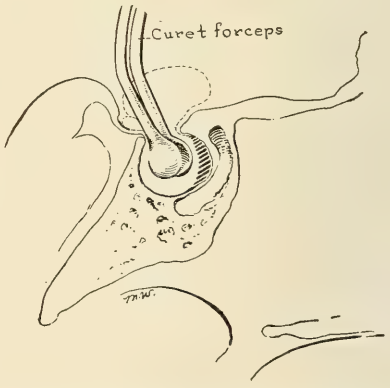

FIG. 30.—THE RESULTS OF THE TRANSFRONTAL INTRADURAL APPROACH, CALLING ATTENTION TO THE REMOVAL OF THE SUPRASELLAR GROWTH AND THE RESECTION OF THE INTRASELLAR PORTION.

The intracranial approach has been employed by a number of surgeons through the anterior or middle fossæ extradurally, and later the dura has been opened over the anterior clinoid process (Figs. 29–31).

The intradural approach affords good exposure of the optic peduncles, the commissure, the internal carotids, the ophthalmic veins, and of the

lesion, thus enabling the surgeon to dissect the tumor from the adjacent structures, and permitting complete removal of the suprasellar, and partial or complete removal of the intrasellar, lesions.

In reviewing the literature it was found that the first successful hypophyseal operation was performed through the extracranial transsphenoidal approach by Schloffer in 1907. His technic has been modified and employed by Hirsch, von Eiselsberg, Hochenegg, Loewe, Cushing, Kanavel, and others. An intracranial subtemporal approach along the floor of the middle fossa extradurally, opening the dura over the anterior clinoid process, was suggested in 1893 by Caton and Paul, and later was employed by Horsley. Because of the excessive bleeding in this procedure it has been abandoned.

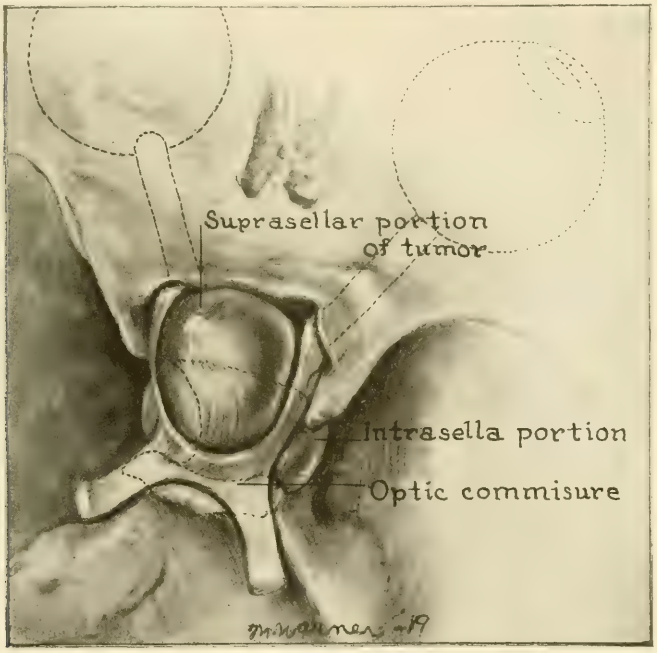

FIG. 31.—HYPOPHYSEAL TUMOR WITH ITS RELATION TO THE SELLA TURCICA, OPTIC PEDUNCLES, AND COMMISSURE, PRODUCING VISUAL DISTURBANCES.

In 1904 Kiliani suggested the transfrontal approach, that is, elevating bilateral osteoplastic frontal flaps, ligating the longitudinal sinus, incising the dura, and elevating the frontal lobes. In 1909 McArthur reported a case in which he made a semicircular incision from the external orbital process to a point above the right ear, opening the dura and elevating the frontal lobe, to approach the sella turcica. A cystic tumor of the hypophysis was exposed, and the contents were partially removed. The trauma to the brain caused the patient's death. In 1912 McArthur called attention to the extradural transfrontal approach.

In 1913 Frazier described the approach to the hypophysis through the anterior cranial fossa, temporarily removing the supraciliary ridge

of the frontal bone and elevating the dura, in addition to resecting the roof of the orbit. The dura was not opened until the anterior clinoid process was exposed.

In the spring of 1917 Heuer called my attention to the possibilities of the intradural approach to the hypophysis. He showed me 2 patients then under his observation at Johns Hopkins' Hospital on whom he had operated successfully by this method.

In 1918 I reported 6 cases in which a hypophysectomy had been done by the intradural approach,[1] as developed at the Mayo Clinic; I have now (September, 1919) operated on 20 patients according to this method.

TECHNIC OF OPERATION

The patient is anesthetized by the inhalation drop method and placed on the operating table with the head at an angle of 45 degrees

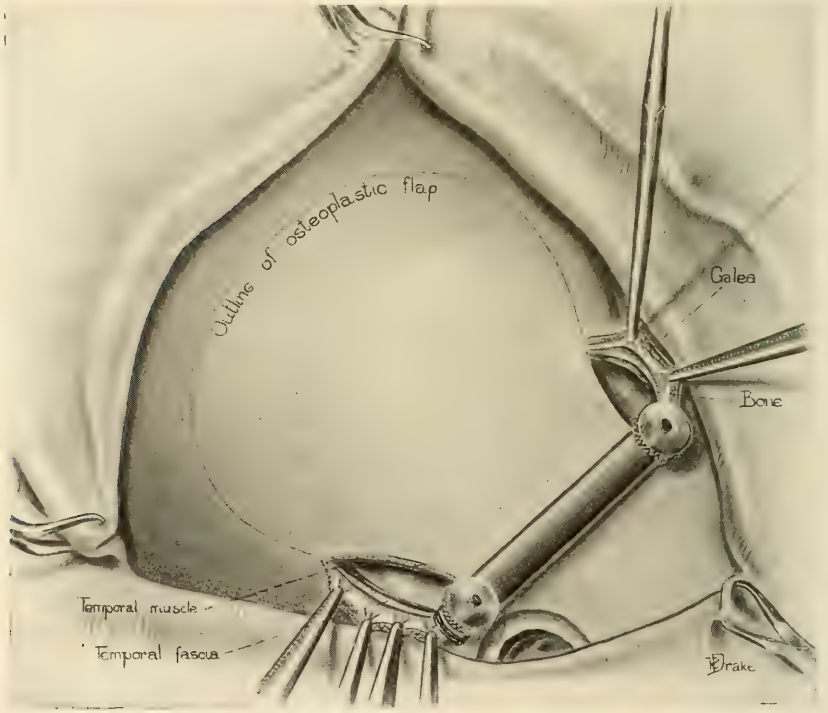

FIG. 32.—PEDICLE CLAMP TO CONTROL BLEEDING IN THE OSTEOPLASTIC FLAP. FORCEPS TO THE APONEUROSIS TO CONTROL BLEEDING ALONG OUTER MARGIN OF INCISION.

with the horizontal plane. After the osteoplastic flap has been turned the head is placed on its occiput, with a lowered head-rest, to permit the natural gravitation of the frontal lobe from the anterior cranial fossa. The anterior limb of the osteoplastic flap corresponds to the margin of the hair-line, beginning 3 cm. posterior to the external angle of the orbit, thus preventing injury to the motor branch supplying the frontal division of the occipitofrontalis. The incision is carried up-

ward, following inside the hair-line to the median line 2 cm. from the longitudinal sinus; it is then extended backward for a distance of 12 cm. and downward posterior to the parietal eminence to a position 4 cm. back of the helix.

The bleeding in the flap is controlled by the application of a pedicle clamp at the base of the flap (Fig. 32). The bleeding in the scalp, aside from that in the flap, is controlled by application of forceps to the aponeurosis (galea) 1 cm. apart, and turned outward gently to compress the margin of the skin. The forceps are tied in groups and left in position during the operation (Fig. 32). The bone-flap is turned by the use of the Hudson drill, the De Villbiss on the sides and the Gigli saw on the upper margin, while the base is broken in the region of the

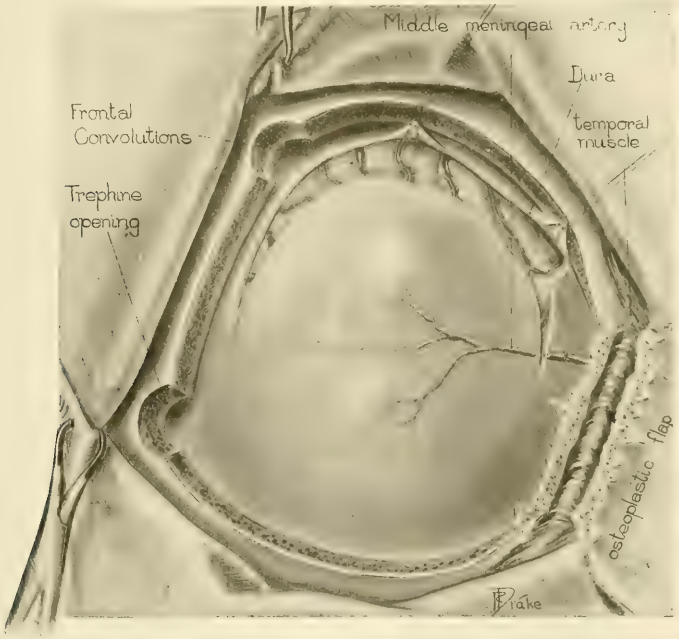

Fig. 33.—Exposure of the Dura, which is Divided Along Its Anterior Margin to Permit the Exposure of the Frontal Lobe.

temporal bone. This produces the beveled effect which assists in holding the flap in place as a lid.

After the dura has been exposed it is incised along the upper anterior and lower margins of the osteoplastic flap incision (Fig. 33), which permits exposure of the frontal lobe, while the frontal margin of the incised dura is held in place by tension sutures of silk. The exposed cortex, as well as the dura, is covered with moist, warm cotton; this, in turn, is covered by rubber tissue (Fig. 34).

During the elevation of the frontal lobe rubber tissue strips are placed gently over the convolutions in a shingle effect in order to give a uniform pressure over the cortex as it is elevated by the retractor (Fig. 35). There is very little difficulty with bleeding during this

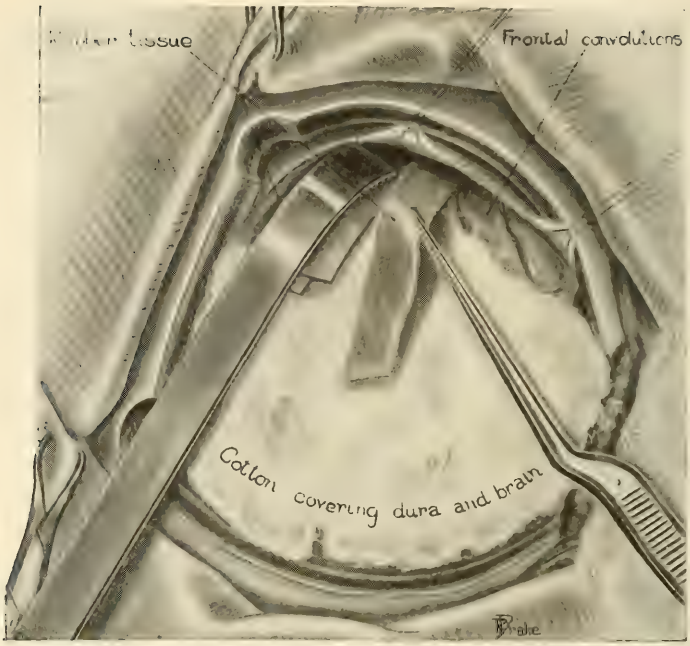

FIG. 34.—ELEVATION OF THE FRONTAL LOPE WITH THE INSERTION OF RUBBER TISSUE STRIPS WHICH ARE APPLIED AS A PROTECTION TO THE BRAIN CORTEX.

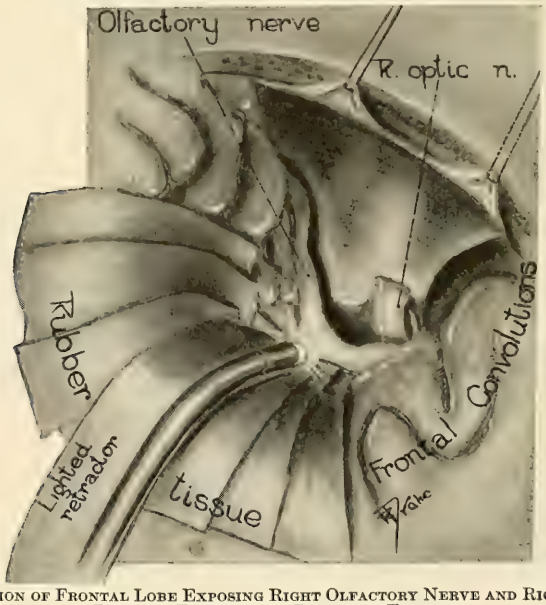

FIG. 35.—ELEVATION OF FRONTAL LOBE EXPOSING RIGHT OLFACTORY NERVE AND RIGHT OPTIC NERVE PRIOR TO EXPOSURE OF PITUITARY TUMOR.

process; occasionally there is a small venous communication between the cortex and the dura. With gentle manipulation the optic commissure and the hypophyseal body are readily exposed. Important land-

marks during the elevation of the frontal lobe are the anterior cranial fossa, the margin of the lesser wing of the sphenoid to the anterior clinoid process, the right optic nerve, and the internal carotid artery.

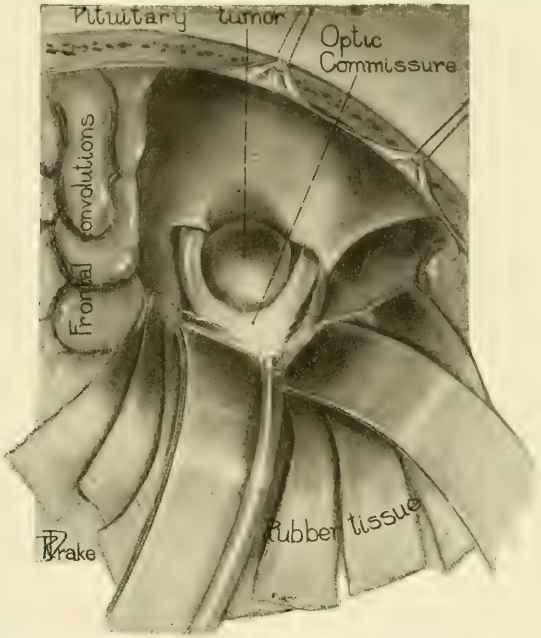

Fig. 36.—(Case 201188). Exposure of Pituitary Tumor with Relation to Optic Nerves and Commissure with a Bitemporal Hemianopsia which is More Marked in the Left Eye.

The procedure is carried on mesially until the commissure, the left optic nerve, and the hypophyseal body are brought into view (Fig. 36). A gentle dissection of the tumor is begun with blunt hooks to free it from

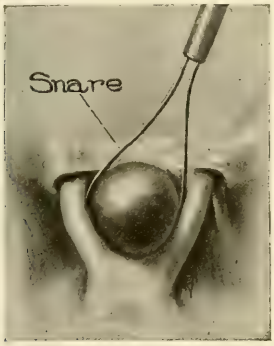

Fig. 37.—Placing the Snare About the Pedicle of the Pituitary Tumor.

Fig. 38.—Appearance of Sella After Tumor Has Been Removed.

the commissure, optic peduncles, and surrounding tissue. Usually the tumor is definitely encapsulated, and if freed from the constricting bands it is readily elevated. Slight bleeding may be controlled by very small

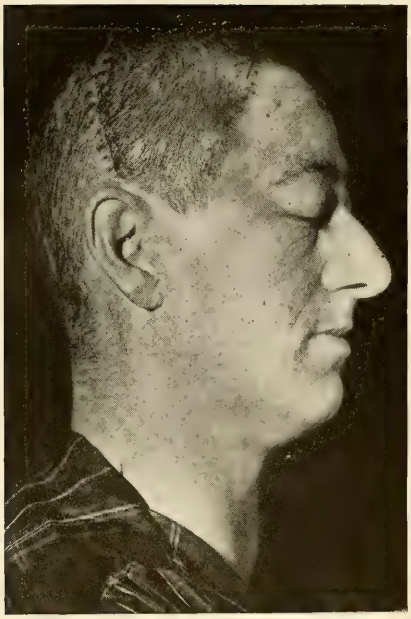

FIG. 39.—(CASE 210605). LATERAL VIEW TWO WEEKS AFTER HYPOPHYSECTOMY, DEMONSTRATING THE LINE OF INCISION AND THE PRESERVATION OF MOTOR POWER IN THE FRONTALIS MUSCLE.

FIG. 40.—(CASE 265097). ANTERIOR VIEW TWO WEEKS AFTER HYPOPHYSECTOMY BY THE INTRADURAL METHOD, HAVING HAD A TRANSSPHENOIDAL SUBSELLAR DECOMPRESSION TWO YEARS PREVIOUS.

FIG. 41.—(CASE 207279). LATERAL VIEW TAKEN EIGHTEEN MONTHS AFTER HYPOPHYSECTOMY, WITH MARKED IMPROVEMENT, HAVING HAD A HISTORY OF BLINDNESS IN THE RIGHT EYE OF MORE THAN TEN YEARS.

FIG. 42.—SAME AS FIG. 41. ANTERIOR VIEW.

pledgets of cotton guarded by long strings of silk to prevent their loss. As the tumor is freed from the surrounding structures (Fig. 37) a snare is applied to its pedicle, which is gradually constricted to control the bleeding and to remove the tumor mass (Fig. 38).

The removal of intrasellar tumors, as well as those having a very slight suprasellar extension, is best accomplished by a division of the capsule and enucleation from within, as an attempt to remove the capsule with the tumor from the enlarged sella is attended with considerable difficulty and bleeding.

Enucleation from within the capsule is accomplished by the use of special forceps in much the same manner that an intracapsular thyroidectomy is performed. This gives excellent results in cases of benign lesions of the pituitary, simulating again the results accomplished by thyroidectomies. If the lesion is a carcinoma or a sarcoma, neither an intracapsular enucleation nor a complete removal of the tumor and its capsule will cure the patient, as the small cavities within the eroded sella are filled with malignant cells that have broken through the capsule (Figs. 39–42).

REPORT OF CASES

In reviewing the 20 cases of tumors of the hypophysis from the Mayo Clinic in which operation was performed by the intradural approach, data were noted as follows: There were 11 females and 9 males; the average age of the patients was thirty-nine years (the youngest nine and the oldest fifty-seven). All the patients presented ocular disturbances extending over a period of from six months to ten years, with an average duration of about eighteen months. In addition to ocular symptoms, cessation of menstruation with marked increase in weight occurred in some instances. Two patients had acromegalia, one a mild type, the other very marked and associated with gigantism.

Examination by the *x*-ray showed two sellas to be perfectly normal, two were slightly enlarged, and sixteen definitely enlarged; eleven of the latter were eroded. The pathologic diagnoses of the tumors in the clinic laboratories were cellular fibromas, gliomas, pituitary cysts, malignant tumors, carcinomas, and sarcomas. The tumors described as malignant showed cellular changes, corresponding, no doubt, to the tumors described by Cushing as strumas. Grossly, the lesions appeared benign. It will be necessary to observe the postoperative course of these patients in order to determine the exact pathology of the tumors.

RESULTS OF OPERATION

Although none of our patients was operated on more than two years and eight months ago, our records show that 3 patients have made excellent recoveries with complete restoration of vision.

Five patients, with marked restoration of function, are still improving. One of these patients entered the clinic with a ten-year history of blindness in one eye, and impaired vision in the other. The impaired eye showed improvement immediately after operation, and three months

after operation the blind eye was beginning to improve. Two of the 5 patients had had subsellar decompressions elsewhere, with only slight improvement. After the radical operation marked improvement occurred in both patients (Figs. 43–53).

Three patients showed immediate slight improvement, one for six months; then the trouble recurred (the tissue in this case was diagnosed

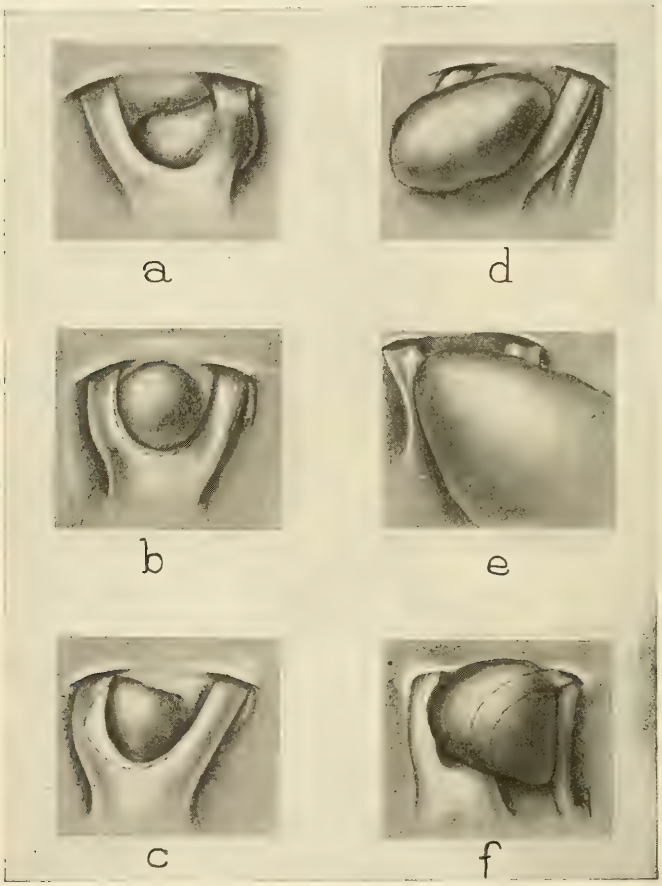

FIG. 43.—EXPOSURE OF PITUITARY TUMOR WITH ITS RELATION TO THE OPTIC NERVES AND COMMISSURE PRODUCING: *a* (CASE 207279), TOTAL BLINDNESS OF THE RIGHT EYE WITH A LEFT TEMPORAL HEMIANOPSIA; *b* (CASE 210605), CONTRACTED LEFT TEMPORAL FIELD ASSOCIATED WITH TYPICAL SYMPTOMS OF ACROMEGALIA; *c* (CASE 207683), TOTAL BLINDNESS IN LEFT EYE AND HEMIANOPSIA OF RIGHT EYE; *d* (CASE 219123), TOTAL BLINDNESS IN LEFT EYE WITH TEMPORAL HEMIANOPSIA OF RIGHT EYE; *e* (CASE 45560), TOTAL BLINDNESS IN RIGHT EYE WITH A TEMPORAL HEMIANOPSIA IN THE LEFT EYE; *f* (CASE 216363), EXPOSURE OF AN INTRACRANIAL PROJECTION OF NASOPHARYNGEAL SARCOMA PRODUCING TOTAL BLINDNESS IN RIGHT EYE AND TEMPORAL HEMIANOPSIA IN LEFT EYE.

as sarcoma). The other 2 patients had large pituitary cysts containing a yellow, gelatinous fluid; they improved markedly for a time, and then vision gradually decreased. Both patients, unfortunately, showed symptoms of hypopituitarism; they were kept on mixed pituitary gland feeding, but the results were not satisfactory.

One patient had a large suprasellar tumor which had invaded the frontal lobe, and was, therefore, inoperable.

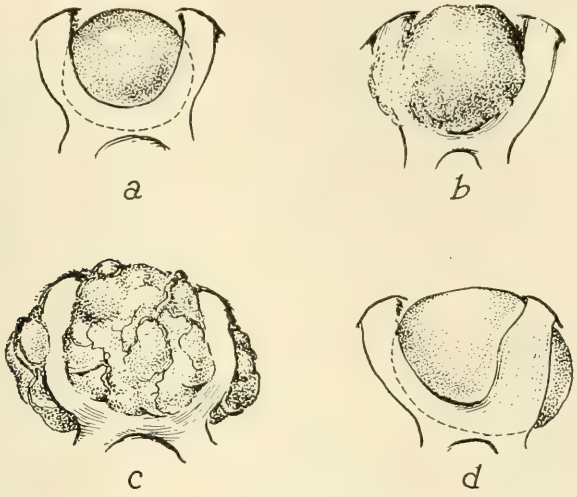

FIG. 44.—*a* (CASE 234782), BITEMPORAL HEMIANOPSIA WITH RESTRICTED NASAL FIELD, DUE TO A MALIGNANT HYPOPHYSEAL CYST, CONTAINING YELLOW GELATINOUS FLUID; *b* (CASE 262796), LOSS OF VISION IN THE LEFT EYE WITH A CONSTRICTED TEMPORAL FIELD IN THE RIGHT EYE, DUE TO A MALIGNANT TUMOR OF THE HYPOPHYSIS (SIX YEAR HISTORY OF BLINDNESS); *c* (CASE 253633), BITEMPORAL HEMIANOPSIA WITH MARKED CONSTRICTION OF THE LEFT NASAL FIELD, DUE TO A ROUND-CELL SARCOMA OF THE HYPOPHYSIS; *d* (CASE 271683), LOSS OF VISION IN THE RIGHT EYE EXCEPT TO CANDLE-LIGHT IN A SMALL NASAL FIELD, WITH BITEMPORAL HEMIANOPSIA OF THE LEFT EYE, DUE TO A MALIGNANT TUMOR. FOLLOWING HYPOPHYSECTOMY IMPROVEMENT WAS QUITE RAPID IN THE LEFT EYE WITH CONSIDERABLE IMPROVEMENT IN THE RIGHT EYE, BUT MUCH SLOWER, PATIENT HAVING HAD A SUBSELLAR DECOMPRESSION FOUR AND ONE-HALF YEARS BEFORE.

One patient developed mental disturbances which probably were due to frontal lobe changes, as it became necessary to ligate several veins on the cortex. The patient gradually improved.

FIG. 45.—(CASE 259278). BITEMPORAL HEMIANOPSIA WITH CONSTRICTED NASAL FIELDS AND A LOSS OF GREEN COLOR PERCEPTION IN THE NASAL FIELD, DUE TO SMALL ROUND-CELL SARCOMA.

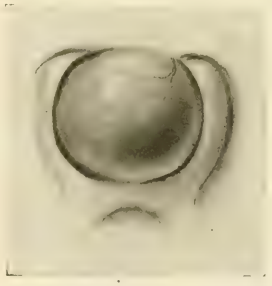

FIG. 46.—(CASE 268798). BITEMPORAL HEMIANOPSIA WITH LOSS OF RED AND GREEN COLOR PERCEPTION IN THE LEFT NASAL FIELD, DUE TO SMALL ROUND-CELL SARCOMA.

One patient had a sarcoma of the sphenoid which had extended posteriorly into the cranium and produced blindness in one eye with a hemianopsia in the other. The sella was eroded, but the tumor could not be palpated from the nasopharynx.

In our series of 20 cases there were 6 deaths; one patient (a male) was an acromegaliac of pronounced type. In this case it was neces-

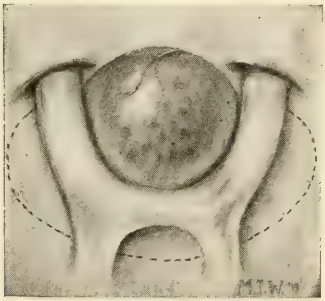

FIG. 47.—(CASE 253290). BITEMPORAL HEMIANOPSIA WITH MARKED CONSTRICTION OF THE LEFT NASAL FIELD WITH A LOSS OF RED AND GREEN COLOR PERCEPTION, DUE TO A LARGE MALIGNANT TUMOR.

The patient had marked acromegaly, which had been coming on for six years.

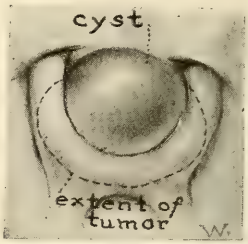

FIG. 48.—(CASE 254897). BITEMPORAL HEMIANOPSIA WITH A LOSS OF COLOR PERCEPTION IN THE RIGHT NASAL FIELD, DUE TO A HYPOPHYSEAL CYST CONTAINING A YELLOW, GELATINOUS FLUID.

The cyst was lined with an epithelial membrane.

FIG. 49.—(CASE 248126). BITEMPORAL HEMIANOPSIA, DUE TO A CARCINOMA OF THE HYPOPHYSIS.

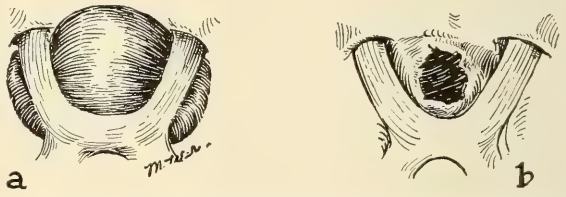

FIG. 50.—(CASE 250408). BITEMPORAL HEMIANOPSIA EXCEPT FOR SLIGHT LIGHT PERCEPTION WITH CONSTRICTED NASAL FIELDS, DUE TO A MALIGNANT TUMOR, WHICH APPEARED GROSSLY TO BE BENIGN.

The patient made a rapid and complete recovery.

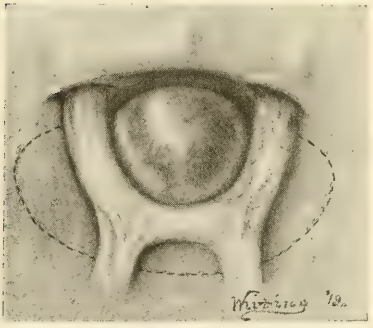

FIG. 51.—(CASE 265097). BITEMPORAL HEMIANOPSIA WITH MARKED CONSTRICTION OF THE NASAL FIELD WITH A LOSS OF GREEN AND RED COLOR PERCEPTION, DUE TO A MALIGNANT TUMOR.

Its removal was followed by rapid recovery in the nasal field, but slower recovery in the temporal fields, the patient having had a subsellar decompression two years previous to the hypophysectomy by the intradural method.

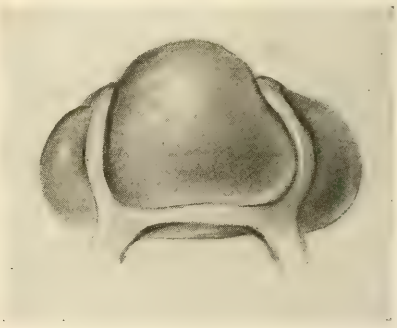

FIG. 52.—(CASE 245366). BLINDNESS OF THE LEFT EYE AND LOSS OF RIGHT TEMPORAL FIELD WITH A MARKEDLY CONSTRICTED RIGHT NASAL FIELD; ALL THE COLOR PERCEPTION LOST, DUE TO A VERY LARGE GLIOMA OF THE HYPOPHYSIS.

sary to divide the operation into two stages: A large osteoplastic flap was turned at the first stage, and a hypophysectomy was done at the

second. In the first operation, unfortunately, the frontal sinus, which was very large and had extended upward into the frontal bone, was opened. After the second operation the patient did well for six days, then suddenly developed an acute cold, with sinusitis, and died in delirium. Necropsy revealed a suppurative frontal sinus with encephalitis.

The other 5 deaths occurred in from twenty-four to seventy-two hours following operation. Two of the patients were males and three were females; all weighed about 200 pounds, and had yellow, pasty skins; they presented symptoms very much the same, that is, visual disturbance, marked increase in weight, lowered mental reaction, low blood-pressure (averaging about 110 systolic and 80 diastolic), and a low metabolic rate. It is fair to assume that these patients were mild hypopituitary types.

Patients with normal metabolic rates rarely experienced any difficulty postoperatively.

FIG. 53.—(CASE 270734). BLINDNESS OF THE LEFT EYE WITH A TEMPORAL HEMIANOPSIA EXCEPT FOR 10-MILLIMETER OBJECTS OF THE RIGHT EYE, WITH A CONSTRICTED RIGHT NASAL FIELD AND A LOSS OF GREEN AND RED COLOR PERCEPTION OF THE WHOLE RIGHT FIELD, DUE TO A MALIGNANT TUMOR.

The intradural approach to the hypophysis has an advantage over the transsphenoidal approach, in that radical removal of a suprasellar or intrasellar lesion can be accomplished with less danger of infection. The transsphenoidal approach is indicated in selected cases where palliative relief is desired. The mortality incident to the intradural approach can be lessened by a careful study of patients to determine the exact metabolic status, and by the avoidance of operations on patients suffering from extensive malignant lesions of the hypophysis.

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CHAPTER XXXII

AMPUTATIONS*

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In an earlier volume of this Surgery the article upon Amputations was written with such care and detail from the standpoint of the civil practitioner that it only remains for me to consider the subject as it relates to the military surgeon and in the knowledge gained in the Great World War.

Experience thus gained has compelled us to modify certain of the rules hitherto laid down, and many operations which in peace time were looked upon with favor have not stood the test of war. The great trauma produced by the modern military missile, with its lacerations and crushing of the limbs as well as rupture of the great vessels, and extensive infections of the soft parts, have changed much of our practice.

Amputation of a limb is desirable and permissible only when the attempt at its preservation would result in the death of the patient from constitutional infection, and the long-standing suppuration consequent upon an attempt to preserve it or where the damage done to the limb is of such a character that there is no possibility of saving it.

It is very generally conceded that there were many unnecessary amputations performed in the early days of the war, but that later, with improved facilities for the care of the wounded and with the institution of better methods of treatment, many limbs were saved that would otherwise have been sacrificed.

The civil surgeon who has not seen the horrible infections and gas gangrenes which were so common in all wounds received on the Flanders and upper French line can have no conception of the difficulties with which the military surgeon had to contend. During the period of trench warfare, and, indeed, until the advance of the allied armies into open fighting in the last year of the war, all of the men were covered with mud and filth from the trenches, and, except in the few fortunately situated hospitals near the front line, the wounded could receive little or no surgical care until they were thoroughly infected. Often the patient received no treatment whatever until many hours and, indeed, sometimes many days had elapsed, while during periods of comparative quiet the wounded could be given first aid and then transported to the rear with reasonable promptness. Much of the operative work was done at the C. C. S., always at railhead back of the British lines. At

*Supplementary to Chapter LXXV, Vol. V, p. 790, and Chapter CXLV, Vol. VI, p. 908.

the time of active fighting the number of casualties were so great and the capacity of these hospitals so overwhelmed that only the most urgent cases could be cared for, the remainder being shipped back on hospital trains to the so-called base hospitals, which were, in reality, evacuation hospitals. Many times in these base hospitals men were brought in covered with the mud and dirt from the firing lines, sometimes but not always with their original field dressings still in place, sometimes, indeed, without any dressing at all, and it is not at all surprising that their wounds should be seriously infected.

The conclusions adopted by the Inter-Allied Surgical Conference, which was composed of representatives from England, Belgium, France, Italy, Japan, Portugal, Serbia, and the United States (the delegates from the United States and Roumania could not attend the first two sessions), were, in brief, as follows (Arch. Méd. et de Pharm. Milit., April, 1917. This was translated and printed in the Medical Bulletin of the American Red Cross Society in France, Vol. I, No. 1):

Amputation is imperative in cases of massive gangrene, especially when complicated with bony or serious vascular lesions and gangrene of a rapidly spreading character, accompanied by alarming conditions, such as a quick fall in blood-pressure and other evidences of systemic depression.

When amputation cannot be done through healthy tissue, short flaps are recommended, these to be held wide apart, or else the no-flap or a guillotine amputation be done at the lowest possible point in the limb.

Very many of the earlier cases of amputation which were brought to the base hospital where I was on duty were of the flapless or guillotine type. During the last year, and especially during the last six months of the war, the majority were operated upon by the flap method, and many of the stumps were closed by primary suture or delayed primary suture.

THE SO-CALLED GUILLOTINE AMPUTATION

"Flapless operation" is a better and more descriptive term to use than "guillotine amputation," although the name is so universal that it will probably always be used. Fitzmaurice-Kelly in 1915 advocated this procedure as a life-saving measure in certain types of infections: in cases of gas gangrene, compound comminuted fracture, and in many multiple wounds. It is not a routine method, but designed to meet certain dangers and for quite definite reasons.

"The present war has raised many surgical problems, but chief of them is the problem of wound infection. All controversies center around this, and the controversialists may be roughly divided into two camps: those who have seen; and those who, not having seen, are altogether unable to believe the conditions with which we have to deal."[1]

The operation as generally practised is not a true lopping of the limb as would be the case if it was cut with one blow; the skin is usually divided by a circular incision, the muscles then divided at the level of

the retracted skin, and next the bone. There have been many modifications of this used in accordance with the amount of available tissue, so that it is better to class them all as flapless amputations. The vast majority of these flapless amputations have been done for gas gangrene

FIG. 54.—HEALED GUILLOTINE OF UPPER ARM. SATISFACTORY STUMP. WEARS ARTIFICIAL ARM WITH COMFORT. (Major Thos. G. Orr, in "Annals of Surgery.")

and other types of violent infection, a secondary amputation, as a rule, being necessary. It enables the surgeon to save a great deal of tissue that otherwise would have to be sacrificed in an attempt at the forma-

FIG. 55.—HEALED OBLIQUE GUILLOTINE OF LOWER THIRD OF THIGH. SCAR MOVABLE OVER BONE. DISCHARGED WITH SATISFACTORY LEG FITTINGS. (Major Thos. G. Orr, in "Annals of Surgery.")

tion of flaps. In the presence of these violent infections flaps very readily slough, and at best are usually distorted, as they must be sutured back so that the wound can be left wide open for free drainage. One modification is the so-called *oblique guillotine*. This makes a very

satisfactory stump, and when the skin is left longer anteriorly than posteriorly quite frequently heal without further operation. If, however, reamputation is necessary the long anterior flap makes a good covering to the end of the stump with the loss of very little bone.

It is quite true that the simple circular or guillotine amputation, with skin, muscle, and bone divided upon the same level, is unfortunate, and necessitates, as a rule, a reamputation, but if this primary amputation is done slowly it permits of a certain amount of retraction of the muscles, and the bone can be removed at a somewhat higher level. A few of these stumps can be finally closed without further operation (Figs. 54, 55).

When reamputation is necessary, after all active infection has subsided, it can be done with the least amount of loss in the length of the

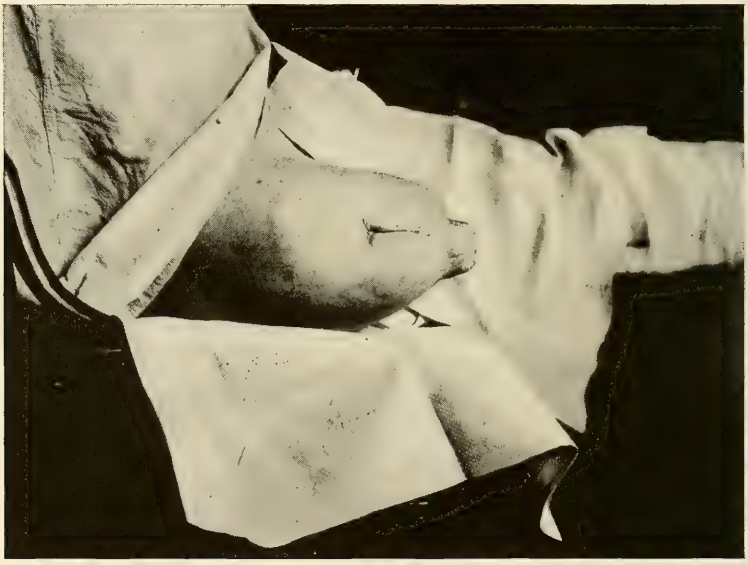

Fig. 56.—Guillotine of Thigh Showing Marked Retraction of Tissues from End of Bone. (Major Thos. G. Orr.)

limb simply by excising the scar, retracting the fleshy part of the stump, and sawing off the bone at a point which will permit of its being easily covered. The periosteum should be cut at or above the level of the bone, as the saw will tear it and aids in the formation of spurs (Fig. 56).

It is better to reamputate than to allow flaps to be drawn in and become adherent and distorted in the process of cicatrization.

While we must agree, in the main, with the condemnation of this method of amputation which Colonel Gibbon[2] has given it, it has a place in war surgery, but it is hardly conceivable that it will ever be necessary to practice it in civil life.

It is distinctly a life-saving measure in the presence of violent infection and of gas gangrene, and much tissue can thus be saved for subsequent flaps which it would otherwise be impossible to save. This

secures the freest drainage, the least sacrifice of tissues, and rapidity of operation.

Secondary hemorrhages were frequent, often necessitating ligature of the femoral arteries in thigh amputations, and the constant dressings for long periods were extremely painful. Sheets of rubber tissue or waxed paper spread over the surfaces of the wound diminished this latter in a measure until the surface was well covered with granulations.

Traction must be employed to draw down the skin and muscles in an effort to cover the bone, but it is not an easy or simple procedure and adds much to the discomfort of the patient (Fig. 57).

In the majority of instances even in the extreme stress of work in a C. C. S., where the wounded can be seen before violent infections

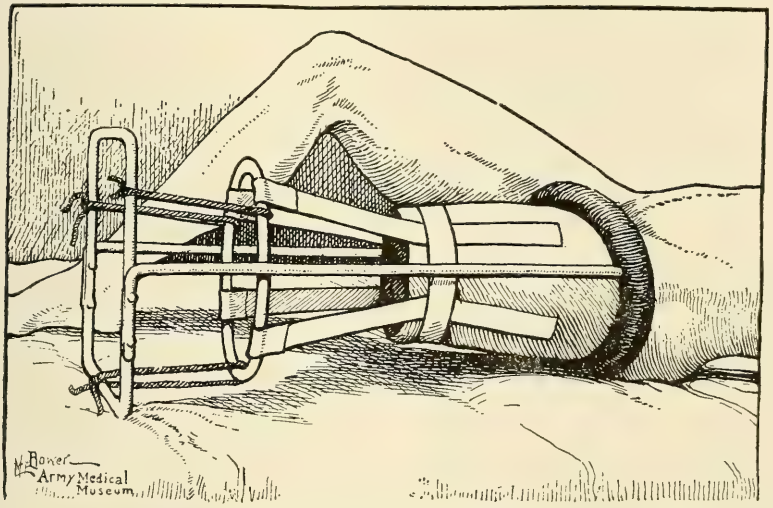

FIG. 57.—STUMP EXTENSION WITH A MODIFIED THOMAS KNEE SPLINT. (Adapted from Sinclair.)

A Thomas knee splint is cut down and a 9-inch square riveted on to the side bars 12 inches beyond the end of stump. An 8-inch circle of aluminum is attached by gauze and glue to the skin of the stump so as to be 6 inches distal to the cut surface. Extension is made from the ring to the square either by tapes or rubber bands. The square acts as a pedestal and also for the attachment of the extensions. Instead of the brace a weight and pulleys may be used; three cords are tied to the ring, each passed through a pulley and all fastened to the weight. ("Review of War Surgery and Medicine," Aug., 1918.)

have developed, flaps can be cut and, if the conditions are doubtful, sutured back and the wound treated as an open one. These flaps can be subsequently brought down and finally sutured.

Major Thomas G. Orr,[3] M. C., in his excellent article upon The Guillotine Amputation gives an interesting account of overseas amputation cases, and I am greatly indebted to him for this series of photographs of stumps and artificial limbs as well as permission to use cuts from his article. He gives a table of 335 patients with amputations from overseas admitted to the U. S. General Hospital No. 26, Fort Des Moines, Iowa. Of these, 199 were flapless operations, or 59 per cent. Of these, 30 per cent. were healed upon admission and 70 per cent. unhealed, and 66 per cent. of the total required reamputation.

As the war progressed primary suture of the flaps as well as delayed primary suture was practised much more frequently.

The wounds we saw from the Flanders and upper French front were treated by various methods. For delayed primary sutures the flaps were brought together by a few retention sutures after the wound had been packed with gauze soaked in various antiseptic solutions. There was no universal and generally accepted methods of treatment employed. The chlorin preparations, eusol with Carrel tubes, were the most common, next to these, salt packs, and finally the use of gauze soaked in 4 per cent. flavine. At the hospitals at the base the Carrel method was used with Dakin's solution when it was possible to obtain a supply accurately compounded. At times all water dressings had to be discontinued owing to the cold and lack of fires. Coal was very scarce and the Dakin solution and eusol would at times freeze in the tubes. Flavine, while not in itself a very reliable antiseptic after infection has developed, seems to have the power of arresting infection. Certainly the wounds brought to us at a British base so treated were in much better condition than when any other method was employed. As Sir Anthony Bowlby stated to me, "These wounds seemed to be in cold storage." Very many of them could be sutured without any form of drainage when they reached the hospitals at the base.

Dichloramin-T was given a very careful and extensive trial, with fair results. The wounds did very well, but no better than under the other antiseptics employed. Its advantages were economy of dressings in gauze and cotton, ease of application, by means of a hand atomizer, and comfort to the patient, as these dressings did not stick to the raw surfaces. When hundreds of severely wounded were arriving at all hours, and when medical officers and nurses were overwhelmed with work, these were distinct advantages.

Simple dry sterile gauze acted well if the usual surgical principle of free dependent drainage was carefully seen to.

Sepsis was so universal that osteoplastic amputations were generally out of the question, as large flaps are required to cover in the end of the bone; they were difficult to obtain, were of low vitality, and readily sloughed.

End-bearing stumps are very desirable, and the best are those when the section has been made through the cancellous bone, but section through compact bone and the medullary cavity of the diaphysis has not prevented the use of an end-bearing pad.

A posterior scar is desirable in all amputations of the leg and thigh, as if the scar is an anterior one it is subjected to irritation from the pressure which must be borne by the front of the lower end of the stump in the action of lifting and swinging forward of the artificial limb. Of course, scars on the end of the bone are not adapted to bearing pressure, although some of them may do so.

While it is recognized that the primary object in all amputations is that of saving life, it should be remembered that next to this should be the suitability of the resulting stump for the fitting of an artificial limb.

"The site, often the method, of a primary amputation is mainly determined by the injury, the amount of shock, the severity of septic infection, and the environment."[4]

"An ideal stump might be defined as one the length of which will best permit the instrument maker to fit the most suitable appliances for the portion of the limb amputated. It should have a linear scar free from puckering or infolding of the skin, with sufficient flap to cover readily the end of the bone, but without redundancy. It should have a pad of fat and subcutaneous tissue over the end of the bone and should not be adherent. The joints above the amputation should have a full range of motion."[5]

It is reasonable to expect that in future wars fewer amputations will be left unsutured, as the great value of primary and delayed closure of wounds has been thoroughly demonstrated.

Traction upon the skin should be used in all cases where the incision is left open, whether the amputation has been done by the circular or short flap methods, and this should be applied as soon as the acute inflammation has subsided. This limits the size of the resulting scar and overcomes retraction, and it may be possible to so pull down the skin that the edges can be approximated by secondary suture. If it be not possible to suture the wound, the skin and muscular tissues are thus kept from retracting until it is safe to remove the projecting bone or to reamputate.

Whenever it is possible in amputations great attention should be paid to future requirements of artificial appliances. The most favorable site for amputations are shown in Charts I and II (Figs. 58, 59), of which the Surgeon-general has been kind enough to permit the reproduction.[6] These show very graphically and much better than any descriptions can the best points at which the amputation should be made.

An amputated stump, as a rule, should be as long as possible, although this may not always be the most useful; but when there is a possibility of a secondary amputation being necessary it is most desirable that the longest possible stump and the maximum amount of skin be provided even if the skin be infected.

Flaps should be cut, even if very irregular, at every primary operation, and should be of sufficient size to cover the stump loosely, and should contain deep fascia and muscle. In the presence of infection and when any doubt arises, the flaps must be left open and stitched back without tension, so that when the acute sepsis has subsided they may be brought forward and sutured. In modified circular amputations and in those with flaps which have not been sutured continuous extension will prevent undue retraction of tissues.

All tissues harbor latent infection which may light up easily, and massage and manipulation may start fresh cellulitis; a fall or bruise also may produce it.

A conical stump may make the fitting of an artificial limb impossible. This is a rare condition, and occurs only in early life before the bones have attained their full development.

I.

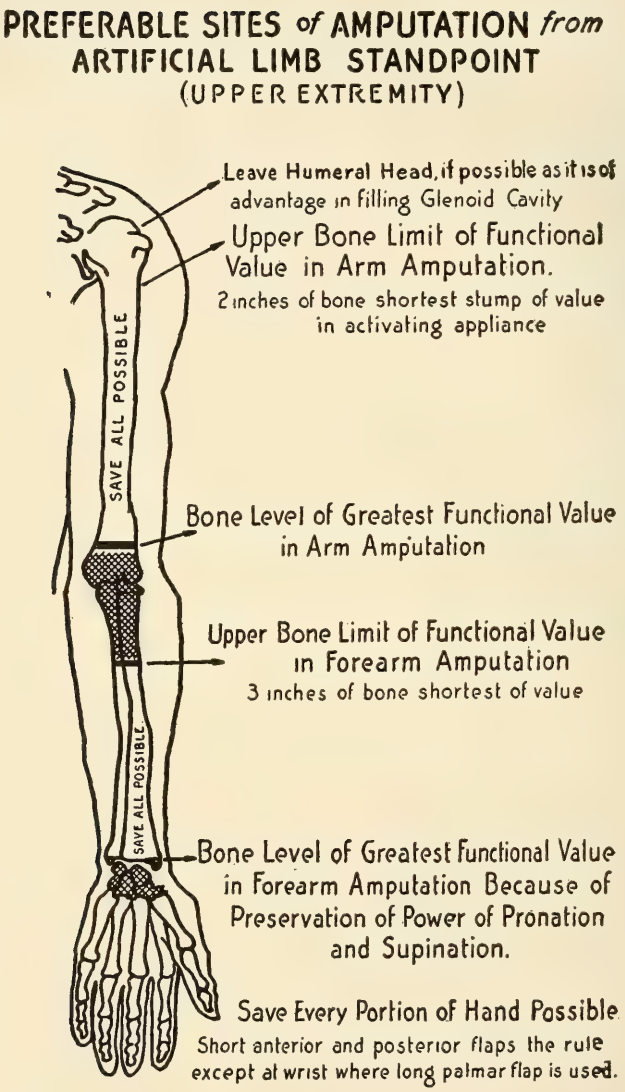
PREFERABLE SITES of AMPUTATION from ARTIFICIAL LIMB STANDPOINT
(UPPER EXTREMITY)
Leave Humeral Head, if possible as it is of advantage in filling Glenoid Cavity
Upper Bone Limit of Functional Value in Arm Amputation.
2 inches of bone shortest stump of value in activating appliance
SAVE ALL POSSIBLE
Bone Level of Greatest Functional Value in Arm Amputation
Upper Bone Limit of Functional Value in Forearm Amputation
3 inches of bone shortest of value
SAVE ALL POSSIBLE
Bone Level of Greatest Functional Value in Forearm Amputation Because of Preservation of Power of Pronation and Supination.
Save Every Portion of Hand Possible
Short anterior and posterior flaps the rule except at wrist where long palmar flap is used.
AMPUTATION (Bone Division) IN SHADED AREA UNSATISFACTORY FROM ARTIFICIAL LIMB STANDPOINT.
ARMY MEDICAL MUSEUM
U.S.

FIG. 58.—COURTESY, "THE MILITARY SURGEON."

The chief growth in the upper extremity is in the upper epiphysis of the humerus and the lower epiphyses of the radius and ulna, the growth in the lower end of the humerus and upper ends of the radius

II

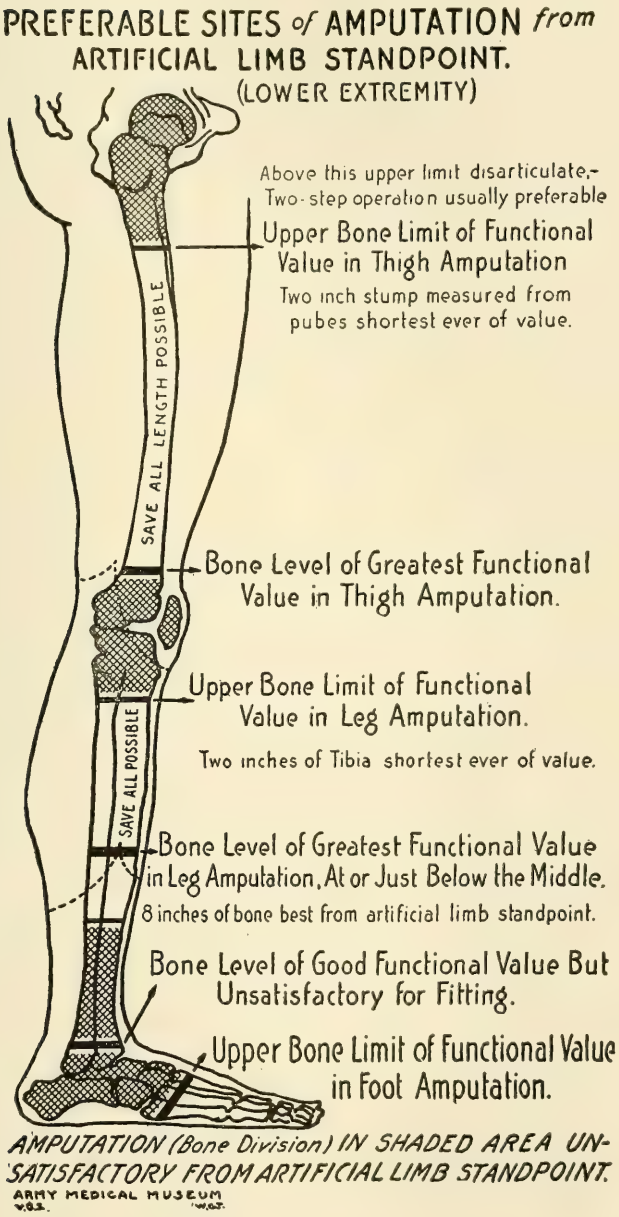
PREFERABLE SITES of AMPUTATION from
ARTIFICIAL LIMB STANDPOINT.
(LOWER EXTREMITY)
Above this upper limit disarticulate,-
Two-step operation usually preferable
Upper Bone Limit of Functional
Value in Thigh Amputation
Two inch stump measured from
pubes shortest ever of value.
SAVE ALL LENGTH POSSIBLE
Bone Level of Greatest Functional
Value in Thigh Amputation.
Upper Bone Limit of Functional
Value in Leg Amputation.
Two inches of Tibia shortest ever of value.
SAVE ALL POSSIBLE
Bone Level of Greatest Functional Value
in Leg Amputation, At or Just Below the Middle.
8 inches of bone best from artificial limb standpoint.
Bone Level of Good Functional Value But
Unsatisfactory for Fitting.
Upper Bone Limit of Functional Value
in Foot Amputation.
AMPUTATION (Bone Division) IN SHADED AREA UN-
SATISFACTORY FROM ARTIFICIAL LIMB STANDPOINT.
ARMY MEDICAL MUSEUM

FIG. 59.—COURTESY, "THE MILITARY SURGEON."

and ulna adding but little to the length of the arm. In the lower extremity the reverse holds good, as the growth is in the lower epiphysis of the femur and the upper epiphyses of the tibia and fibula. If,

therefore, an amputation be done above the elbow or below the knee in a young child a marked growth may be expected in the length of the bones.

As a rule, the growth of the soft parts keeps pace with the bones, and there is no trouble, but if the growth of the bone outstrips that of the soft parts, a conical stump results. This brings tension upon the stump and causes it to become cone shaped and produce pain. A reamputation must then be done to permit of the fitting of a socket for an artificial limb.[7] While this is usually only seen in early childhood, it is possible that it may occur in certain of the very young soldiers (many in the allied armies were not over seventeen years of age) and before the full growth of bone had been attained.

When there is a large terminal scar with ulceration in a conical stump, reamputation should be considered. Chisholm[8] gives very excellent suggestions for the operations in reamputations, and urges against the inclusion of muscle in the flaps, and states that it is far better to sacrifice a little extra bone in order to secure sound tissues than to run the risk of failure and the needs for further operation at a later date. The flaps should be freed from the scar. Reamputation must never be attempted in the presence of an active septic wound, although healthy granulations need not be a contraindication.

Hemostasis must be complete, and if a clot be formed within the wound, it must be cleaned out under a general anesthetic, then sutured, and drained.

Beveling of the anterior ridge of the tibia must be done and the fibula divided at least $\frac{1}{4}$ inch higher in all amputations below the knee, and a posterior splint applied to the limb at the time of the operation to prevent knee flexion.

Pain in the stump, localized or diffused, is one of the chief sources of difficulty in fitting an artificial limb. All stumps, therefore, should be carefully and systematically examined for local tenderness whether the patient complains or not. Pain may be due to one or more bulbous nerve-endings, or a nerve filament may be adherent to the bone or scar, and as this is one of the frequent causes of pain, it emphasizes the importance of identifying and cutting short the principal nerves at the time of the primary amputation. Diffused tenderness is usually due to periostitis or necrosis.

Pain, local or diffused, may also be due to bony spicules projecting from the bone; these osteophytes are more common in stumps of the middle of the thigh and may require removal before an artificial limb can be worn. They can be easily detected by the *x*-rays.[9]

Encysted foreign bodies and without suppuration may be a cause of pain. This also shows the necessity for *x*-ray examination of every painful stump. But by far the most common causes of pain are in the bone itself—osteitis, periostitis, and small areas of osteomyelitis.

At the time of primary amputation the principal nerves should be cut as short as possible and should not be included in the ligature of the vessels. To prevent painful nerve-endings the following procedures have been recommended (British Memorandum, p. 5):

(1) Forcible crushing of the nerve end and ligature of the sheath at the crushed part.

(2) Suturing of the sheath over the divided end.

(3) Removal of a wedge from the end before suturing.

These last two methods can only be practised at the secondary operation, but the first is said to limit the spread of infection to the nerve trunk.

As long as edema of the stump remains, the fitting of an artificial limb should not be undertaken. A swollen and tender stump may be due to improper bandaging.

Persistent sinuses cause delay in the fitting of an artificial limb, and may be due to a sequestrum, osteomyelitis, septic ligatures, metallic foreign bodies, and to retained clothing, as well as uncollapsible walls of fibrous tissue. These limbs should always be *x*-rayed, the sinus laid open, excised when possible, and careful search made for any foreign substance.

The curet must be used with caution, but if there be a cavity in the bone it must be freely laid open.

Poor circulation in the stump, most often seen in the lower third of the arm and leg, is frequently a cause of ulceration, more especially in debilitated subjects, as well as in the intemperate and those with constitutional disease; and where there is too much tension in the scar, owing to the flaps being too short. When ulceration occurs after the artificial limb has been worn it is usually caused by a poorly fitting socket allowing friction and unequal pressure. A socket too tight at the top may also cause ulceration by constricting the circulation and producing edema.

The scars should be excised and skin-grafting should never be attempted. While a large scar, even if adherent to the end of the bone, does not necessarily prevent the wearing of an artificial limb, it is very undesirable, and if there be recurrent and persistent ulceration, excision of the scar or reamputation must be done. The soft tissues may atrophy to such an extent as to provide insufficient covering to the bone, and permits of pain and ulceration by dragging upon the scar.

The end of the bone should be covered by the deeper soft parts, so that the cutaneous scar does not become adherent to it. If the flaps are too thin they are liable to slough, and it is very important to secure healing by the apposition of the skin edges rather than by granulation tissues or grafts. The scar should be placed where it is not subject to pressure and a linear scar secured if possible. In the upper limbs there is no weight bearing, and the position of the scar is not so important, for the pressure of the artificial arm is only on the circumference. For this reason a terminal scar is desirable, but not essential. In the lower limb, however, it is preferable that the scar shall not be terminal in order that weight bearing may be possible.

Disarticulation, except in the case of the hip and shoulder, does not give satisfactory stumps. The resulting stump is more or less bulbous when the amputation has been made through a joint, and this

becomes more exaggerated with the shrinking of the soft parts, and makes the fitting of an artificial limb much more difficult. As the artificial limb must be wider than the natural one, it is consequently very unsightly, and makes it almost impossible to fit a rigid socket, which is always desirable.

Open amputation through the knee-joint, disarticulation, has a limited place as a life saver in certain of the severe infections of the joint with extensive burrowing of pus up the thigh and in violent gas gangrene. It diminishes shock and preserves that maximum amount of tissue for creating a long serviceable stump, for all of these cases require reamputation, and as the bone is not sawed across it lessens the dangers of destructive infections of the marrow cavity.[10]

AMPUTATIONS OF THE UPPER EXTREMITY

The importance of saving as much as possible of a **thumb** or of **one finger** cannot be overestimated, as it is much more valuable than any possible artificial appliance. But if there be extensive destruction of the metacarpal bones, with much loss of tendons and great damage to the soft parts, it is often better to amputate the finger early than to permit of long-standing suppuration with the resulting stiff, crippled, and almost useless hand.

Amputation at the **wrist** should never be done if it is at all possible to retain any portion of the hand or carpus.

The best site is at the junction of the middle and lower third *of the forearm.* Every effort should be made to preserve all of the forearm above this point. A short forearm stump, 2 to 4 inches below the tip of the olecranon, makes it very difficult to adjust an artificial arm, as the short stump slips out of the socket during active movements of the elbow, while at the same time there is loss of leverage. Short anterior and posterior flaps give the best results. Amputation at the wrist-joint should be done when possible, as it preserves the power of pronation and supination, and if the tissues at all warrant, a long palmar flap is best.

In all amputations of the forearm care should be taken to prevent firm adhesions between the two bones, as pronation and supination are most useful with any form of artificial arm.

There are no advantages in amputations through the **elbow-joint** over that of immediately above it. It makes the fitting of an artificial limb more difficult owing to the end of this stump being too broad laterally, and an arm socket cannot be accurately fitted except by lacing it up the front.

The **humerus** should be divided as low as possible, immediately above the epicondyles, for the same reasons which make it inadvisable to disarticulate at the elbow, as the stump will have a bulbous end.

Amputation through or immediately below the **shoulder-joint** means that the patient has no control over the artificial arm, except in certain very complicated and expensive types of apparatus, which are not of universal application. But some power over the movements of

an artificial limb can be obtained with a stump only 2 inches in length. To gain greater purchase the anterior axillary fold may be cut away, thus lengthening the stump. The attachments of the muscles of the shoulder, the pectoralis major, latissimus dorsi, and the teres major, when severed, materially increase the available length of the stump.

If the head of the humerus can be preserved it rounds out the shoulder and diminishes the deformity. It is very important to prevent adduction-contraction during the healing of the wound.

AMPUTATIONS OF THE LOWER EXTREMITY

In injuries of the **foot** the conditions are the opposite from those of the hand. A solitary toe soon becomes deflected and troublesome and not even the great toe should be kept alone. In amputation the heads of the metatarsal bones should be preserved, especially that of the great toe. Partial amputations of the foot have not proved of very great value and the resulting stumps have not been of much practical use. The Syme amputation is by far the best, the flaps not too large, and should be shaped to fit closely over the ends of the tibia and fibula, and should never be loose and redundant, as this makes a bulbous end to the stump. The plantar nerve should be taken out of the flap and the posterior tibial nerve cut well above the malleolus. It is best to cut the bone at least $\frac{1}{4}$ inch above the articulation of the tibia. Internal and anterior flaps may be made, but they do not make a good stump for weight bearing.

A **Lisfranc** amputation is seldom possible, and in the septic condition of war the trophic changes produce painful and unsatisfactory stumps. In perfectly clean cases, if the ends of the tarsal bones are well covered, it may make a fairly useful stump.

A **Chopart** amputation gives a broad walking surface, but the contractions of the tendo achillis soon raises the heel and brings the scar at the lowest part of the foot. It is, therefore, not satisfactory, as a rule, for one who must be on his feet much of the time.

The **Pirogoff** and any form of subastragaloid amputations are very difficult to fit with artificial feet.

In all amputations of the **leg below the middle,** which is the point of greatest value for the wearing of an artificial limb, the flaps are wanting in vitality, while above this point there is diminished power of leverage. The tibia should be cut transversely with the anterior border beveled to prevent pressure upon the thin anterior flap. The fibula must be divided $\frac{3}{4}$ inch higher than the tibia. If this must be divided less than $3\frac{3}{4}$ inches from the knee-joint, it is best to remove the fibula entirely. The flaps may be antero-internal or postero-external, and the line of suture should be away from the rest of the tibia.

Terminal scars must be avoided, and the flaps should include all the muscles. Flexion at the knee is easily acquired and very difficult to overcome, and must be guarded against by splinting and exercises of the joint begun early and persisted in. Kneeling stumps are very

undesirable and only permissible when the stump is painful and too tender for end bearing.

Fig. 60.—Pelvic Cradle or Tilting Table as Supplied by the Canadian Government. (Lieut.-Col. C. L. Starr.)

Amputation through the **knee-joint** or through the condyles is frequently of value as a life-saving measure. It does not give sufficient room for an artificial knee-joint and makes this wide, bulky, and clumsy.

Under the septic conditions of war the transplantation of the patella upon cut surfaces of the condyles, the Stokes-Gritti amputation, is

usually followed by non-union or necrosis, and should never be undertaken except in perfectly clean cases, when the liability to infection is very slight, or as a late secondary operation after all infection has subsided.

In all knee-joint amputations the patella should be retained, so that at the secondary operation its fascial covering may be used and the flaps left as long as possible.

The **femur** should be divided as low down as possible to permit of the greatest amount of leverage in the stump of the thigh. Avoid terminal scars, especially in fleshy thighs, as the pressure of the bucket of the artificial limb pushes up the tissues and drags upon the scar. It should be remembered that this artificial limb takes its bearing from the tuberosities of the ischium and partly from the soft parts of the thigh. The flaps may be anteroposterior, long anterolateral, or short posterointernal with the scars behind, which give the best stump.

Division of the bone 2 inches below the lesser trochanter makes it very difficult to fit an efficient artificial limb, and it is much better to cut through the greater trochanter than to disarticulate. Disarticulation at the primary operation increases the risk very materially.

When the amputation of the thigh has been done very high up, above 2 inches as measured from the pubes (and often the condition of the patient does not warrant or demand an attempt at disarticulation of the joint), the end of the bone projects laterally. For this a shelf may be made in the socket of the artificial limb upon which it can rest, and often answers very well. The short stump sits upon a padded surface and gives a comfortable and much more useful artificial limb than if the head of the bone is removed.

In amputating at the **hip-joint** the anterior incision which exposes the femoral vessels first is the best method, as the resulting stump lies close to the pelvis, while the large fleshy mass left by an external incision interferes with the fitting of the pelvic attachment, the "turning-table" socket of an artificial limb (Fig. 60).

AMPUTATION STUMPS

The necessities of the war and the extraordinary number of septic wounds which healed with large, generally terminal scars, have produced many atypical stumps, but the rules as laid down by manufacturers of artificial limbs as to preferable amputation sites still hold good. Terminal scars are no longer a bar to the fitting of an artificial limb, as through toughening the scar and rendering it movable over the bone the stumps may be fitted with provisional limbs even with end-bearing scars, and without discomfort.

In all cases when sound healing has not occurred over the protruding bone, as well as in those stumps with large, poorly nourished scars, and when the site of the primary amputation is ill adapted to the wearing of an artificial limb, reamputation should be done. Irregular, tender scars, ulceration, and persistent eczema of the surrounding skin require plastic operations.

Bone-spurs are quite common, but unless they cause trouble need not be removed; the true test is the ability to fit and wear an artificial limb.

Sequestra of bones are very common in infected stumps.

At each dressing before the wound is healed the stump should be moved in all directions and to the full limit in the opposite direction from that in which contraction is likely to develop.[11]

The forearm stump movement should be carried out in full supination and extension; in the upper arm an upward and backward motion; in the lower leg an extension, and in the thigh amputation, in extension and adduction. It is wise to carry this to the point of hyperextension. Particular attention must be given to this extension in all thigh amputations because of the tendency to flexion contraction, and during the healing of the wound these movements must be frequent, even twice daily, as well as changes of the position of the pillow upon which the stump is resting; taking it from under the stump and placing it under the buttock to favor hyperextension. The forearm should be dressed in supination.

Systematic tests of the range of joint motion should be made by the surgeon at frequent and regular intervals, especially in bed-ridden cases. Complete flexion and extension of the elbow with rotation of the radial head must be secured, as the value of pronation and supination must be borne in mind in the future use of an artificial hand and arm. All the movements of the shoulder must be carried out. Upward, downward, forward, backward, and circumduction are the movements that can readily be tested while the patient is lying at the edge of the bed, the upward and backward movement being the most important.

The treatment of the stump should be systematically carried out; this consists in daily massage, very gentle at first and gradually increasing in force as the tolerance of the stump will permit. The stump should then be firmly bandaged with a bias flannel bandage. Attempts should then be made to harden the stump by pressing the bandaged end against a cushion, and hot packs, warm baths, and electric-light baths should be used to improve the circulation and hasten absorption. All this must be undertaken gradually. As soon as the patient can be out of bed, he should attempt to bear his weight upon the end of the stump by resting it upon a stool or side of the bed, and finally, when the wound has thoroughly healed, he should begin (carefully at first) to hammer the end of the stump against a stool, in imitation of the pounding which takes place in walking upon an end-bearing stump.

It is to be remembered that the knee is normally in a few degrees of recurvation.

In the hip care must be exercised that no flexion deformity be permitted to develop. This is a condition very easily acquired and extremely difficult to overcome, and when present interferes very much with the proper use of an artificial limb.

From the prosthetic point of view the chief requirements of the good stump as laid down by the British Government[4] are the following:

(1) Satisfactory length.
(2) A good mobile covering.
(3) A firm, non-adherent cicatrix.
(4) Freedom from pain or tenderness.
(5) Absence of edema.
(6) Shrinkage and consolidation of all parts of the stump.
(7) Free normal mobility of the joints above.

In civil practice the surgeon has been usually content with curing his patient and securing prompt healing of the wound. Sufficient care has not been exercised in obtaining and preparing a stump for the fitting of an artificial limb. The preferable sites for amputation to secure the best function has been pretty generally agreed upon by surgeons and manufacturers of these appliances, but it has only been of late that the medical profession has become deeply interested in the fitting of artificial limbs as developed in the reconstruction war hospitals both in Europe and in this country.

Every amputation should be so planned that the patient's future comfort and earning capacity will be maintained, and that he be treated as any other patient requiring braces and appliances.

An early fitting of a temporary limb should be insisted upon, and he should not be turned loose to be supplied with an artificial limb by an instrument maker without proper supervision by the surgeons.

There has been a very marked improvement in the results obtained in the use of artificial appliances. This is due very largely to the knowledge gained by surgeons in the fitting of artificial limbs and their recognition of the importance of the after-care of the stump and to the more thorough and systematic training in the use of apparatus.

In learning to walk with an artificial limb it is not only necessary to learn to carry out the correct movements of the stump, but the sound limb must be taught to refrain from excessive movements brought about by co-ordination with the stump. This applies to artificial appliances to the lower limbs and not to those of the upper extremity.

In the Review of War Surgery and Medicine (November, 1918, page 34) there is an excellent account of the work of Professor R. du Bois Reymond's studies upon the gait of patients wearing artificial limbs. By the use of Geissler tubes secured to the segments of the limbs parallel to their axes while the patient is walking about a spark is passed through the tubes and an image is made upon a photographic plate. These show the great differences in the gait of the artificial and natural limbs, and that a man in his effort at walking makes too energetic movements of his stump, and this involuntary effort causes too great activity of the sound limb as well.

ARTIFICIAL ARMS AND LEGS

The chief requirement of an artificial arm is motion, and the appliance must be made to do a large part of the work of the lost extremity and the efficiency of the hand. Now usefulness depends upon strength, for touch is gone, and the actions of the hand must be restricted to

grasping movements of a simple character. The finer movements are impossible.

We must distinguish between the one armed and the armless. The one armed will use the artificial appliances for a very limited number of movements, depending, as indeed, we all do, upon one hand to do the most important acts, the other hand being simply a helper. Following the loss of one hand the other becomes more educated; and surprising skill is often developed, so that one hand can do almost the work of two.

Weighing, carrying, and holding are the functions of the auxiliary hand, and the largest number of acts which it performs is that of a

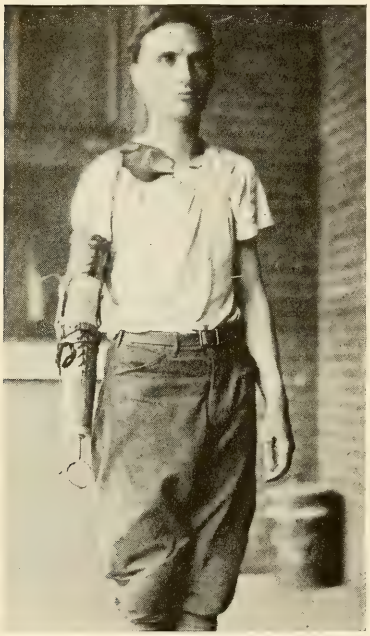

FIG. 61.—TYPE OF PROVISIONAL ARM WITH LACED LEATHER FOREARM SOCKET AND HOOK AS FURNISHED BY THE U. S. GOVERNMENT. (Major Thomas G. Orr.)

FIG. 62.—SAME TYPE OF ARM WITH HAND AS FURNISHED BY THE U. S. GOVERNMENT. (Major Thomas G. Orr.)

weight or guide to prevent the object which is being worked by the other hand from moving: carrying and the holding of tools, helping the other hand.[12]

Any type of artificial arm or stump if long enough will act as a weight, but for carrying purposes there must be some form of hook, and for holding a clamp. A hook is not difficult to provide, but the action of a clamp is not easy to supply, and a good combination has not yet been devised (Figs. 61, 62).

"In studying the problem of the artificial arm one is struck again and again by the value of relatively simple appliances and the importance of thorough training in their use. With a simple wrist strap an armless man is able to dress and feed himself and do most of his

ordinary daily acts. A strap over the shoulder, properly provided with a ring, is sufficient to enable the one-armed man to plow, use a wheelbarrow, spade, and pitch hay. A single working appliance has enabled a man who suffered a disarticulation of the right shoulder and an amputation of the left forearm to be entirely independent. After all, it is a matter of a little brains and much perseverance"[12] (Fig. 63).

D. F. Martin (La Prothese du Membre Inférieur, Martin, Paris, 1918) describes in detail the various types of artificial limbs made at the Ambulance de L'Ocean (La Panne), and lays great stress upon the importance of a provisional apparatus made with a plaster-of-Paris socket, with rods of wood, and carefully measured (Fig. 64). An outline drawing of the shape and peculiarities of the sound limb is made to which the

FIG. 63.—THIS SIMPLE WRIST STRAP IS USED TO HOLD ALL ORDINARY ARTICLES, SUCH AS A COMB, BUTTON HOOK, AND TOOTH-BRUSH. IT IS THE DEVICE OF MR. YOUNG, OF NEW YORK, WHO HAS LOST BOTH HANDS. ("Review of War Surgery and Medicine," Aug., 1918.)

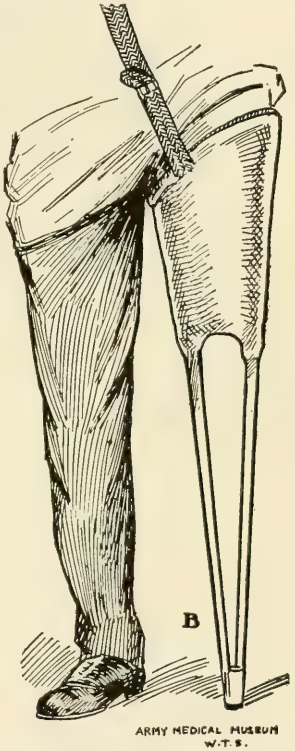

FIG. 64.—*B*, THE PEG-LEG APPLIED. ("Review of War Surgery and Medicine," Aug., 1918.)

artificial limb must correspond as far as possible. This is very important to enable the patient to walk freely and naturally, not to speak of the great advantage of appearance. From this is molded plaster of Paris accurately measured from the sound limb. Upon the mold is glued strips of wood, long thin shavings, which make a leg very strong, light in weight, and at a small cost. While this looks very simple it requires experience and great skill (Fig. 65)

We are fortunate in America in having many manufacturers of artificial limbs varying in design and material, but largely based upon

the same principles. It is therefore advisable that the active making of this apparatus be given into their hands. They are almost all good, some, of course, better than others in certain of their details, but the principles vary but little.

To anticipate the great needs for artificial limbs which the army authorities believed would be necessary, and which would surely be needed if the war had continued only a few months longer, Colonel Silver, of the Medical Corps, made a very thorough and exhaustive study of the whole subject, and finally selected a design for both temporary and permanent limbs. These proved of such value that quantity production was undertaken with the most gratifying results (Figs. 66–69).

FIG. 65.—DOUBLE THIGH AMPUTATION, MIDDLE THIRD.

Wearing very short plaster pilons as a beginning. After learning to balance well on these he was given full length legs. (Major Thomas G. Orr.)

In England temporary peg legs of various sorts were supplied, and the men were encouraged to discard their crutches. I saw one man at Rochampton with a high amputation of the left thigh who walked $3\frac{1}{2}$ miles the first day he was given a fiber paper cone leg, and this without crutch or cane. After the limb is fitted in the rough and the cripple put through systematic instruction as to how to use it, he is made to exercise in front of large mirrors, and to walk about the grounds of the hospitals over paths of different grades and materials; obstacles of all sorts had to be overcome to teach the wearer how to surmount difficulties such as he would be likely to encounter in his every-day life, while at the same time modifications were made in the limb he was trying out as to length, weight, and fit. It was not until he had obtained a reasonable proficiency in handling himself in many difficult and trying circumstances that his limb was finished and he was finally turned out to look after himself. The ability quickly to use any form of appliance depends upon the individual, some acquire in a few days the balance and skill in walking which may take others weeks to attain.

At the Prince of Wales Hospital in Cardiff particular attention was given to this education in walking, and a great variety of obstacles in the walks in the Garden had to be surmounted.

In Great Britain the number of the mutilated who required artificial appliances was so overwhelming that their needs could not be supplied, and many months would often intervene before they could be fitted. Temporary limbs were improvised from heavy fiber paper

cones, padded with saddler's felt, and it was surprising how well these answered to enable the men to walk about.

At Rochampton, where there were always 900 men being fitted with limbs, it usually required six weeks and often much longer for a man to gain admittance after his application was received. Not only was the capacity of these various amputation hospitals necessarily

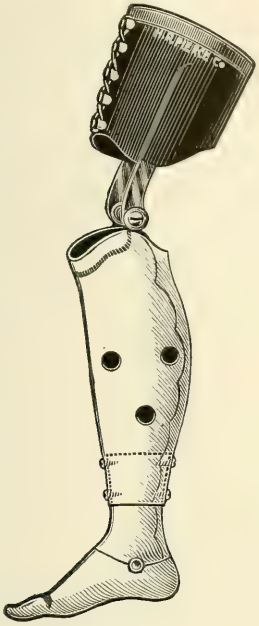

FIG. 66.

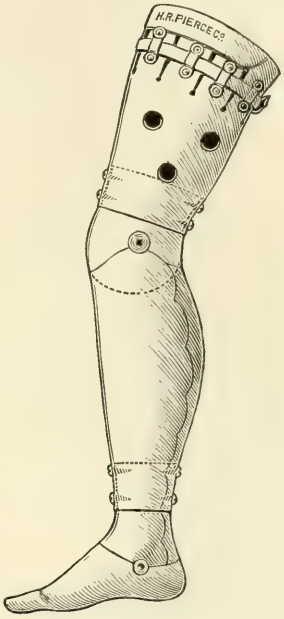

FIG. 67.

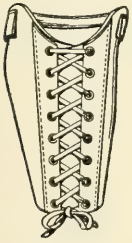

FIG. 68.

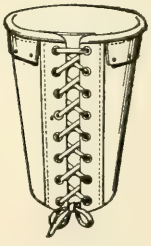

FIG. 69.

FIGS. 66–69.—TEMPORARY ARTIFICIAL LIMBS, ADJUSTABLE.
Figs. 66 and 67.—Amputation of leg. Figs. 68 and 69.—Laced sockets.

limited, but every war hospital had a department for the manufacture of artificial limbs at Shephards Bush, Leeds, Edinburgh, Liverpool, Bristol, and Cardiff, as well as many others, but the number of workmen in any degree competent to make and fit limbs was limited. More men had to be trained to the work, generally handy mechanics who had been in the army and personally suffered from the loss of a limb. The skill which they developed in spite of their handicap was truly

marvelous, both in the dexterity with which they managed their own artificial limbs, as well as the character of the work they turned out.

In order to play fair with the manufacturers of limbs and that favoritism could not be charged, all were given an equal chance to supply limbs. Each maker who wished could have his own shop at the hospital (I am speaking more especially of Rochampton), where he could have his own workmen, use his own methods of construction, materials and design, provided these conformed within reason with the type of limb which experience in the medical department of the army had demonstrated as being of value. Orders for limbs were given to the manufacturers and paid for by the Government. Various centers were established throughout the British Isles for the repairs of limbs

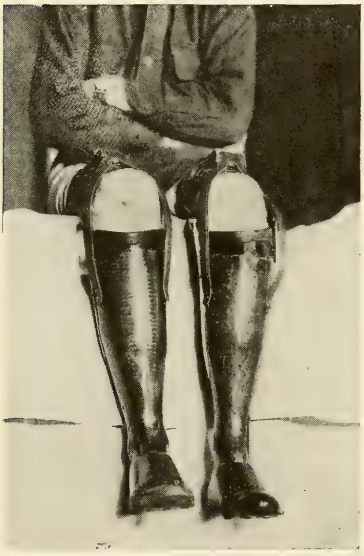

FIG. 70.—FITTED WITH GOVERNMENT SUPPLIED PROVISIONAL LEGS.
The sockets are made of building paper and glue. (Major Thomas G. Orr.)

FIG. 71.—WALKER FOR TRAINING DOUBLE AMPUTATIONS TO WALK. (Major Thomas G. Orr.)

and for those which required modification, to diminish as much as possible long journeys for the patients.

Fortunately for our own army, the need for such elaborate establishments throughout the country is far less (exact statistics are not at this time available from the Surgeon-general's office), but the numbers are running into thousands.

Appearance counts for little if there be comfort, stability, efficient progression, and lightness. A peg leg with a broad base for farm laborers and for those who must be on their feet most of the day has proved the most practical.

Stability varies with the length of the natural limb as well as the length of the segment through which the amputation has been made.

The socket in short stumps may require extension by laced sockets, and in thigh stumps by a pelvic band, while at other times the joints must be stiffened at the knee and hip to give sufficient stability, thus necessarily interfering with the gait in walking (Figs. 70, 71).

The best form of support is through a direct end-bearing stump, and investigation should be made of how the weight of the body is transmitted through both the natural and artificial limbs. Indirect or lateral bearing by dragging upon the tissues often cause ulceration of the skin, and sooner or later will give trouble, and requires much care on the part of the patient to keep the stump in condition. Flaps that are too redundant wrinkle, and in the creases so formed eczema is liable to develop.

Progression depends upon good muscular power in limbs above the site of amputation, as walking with short stumps is always fatiguing. For this reason the artificial limb should be as light as possible, as the muscle power is diminished by disuse, and interference with the insertion of the muscles render some of them entirely ineffective.

A man's value as a worker able to support himself and a family depends not only upon his ability to do a certain kind of work but also upon his ability to keep on doing this from day to day. And it is this question which must be considered by the surgeon. How much is the man's earning capacity lessened by his amputation? The answer to that question does not depend upon the site of the amputation or the length of the stump, for in many instances the capacity for work is good when the amputation is comparatively high, and again in many low amputations the efficiency is poor.

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CHAPTER XXXIII

OPERATIONS ON BONES AND JOINTS*

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Since the chapters on Operations on Bones and Joints were published, in Volumes V and VI, some significant contributions to this

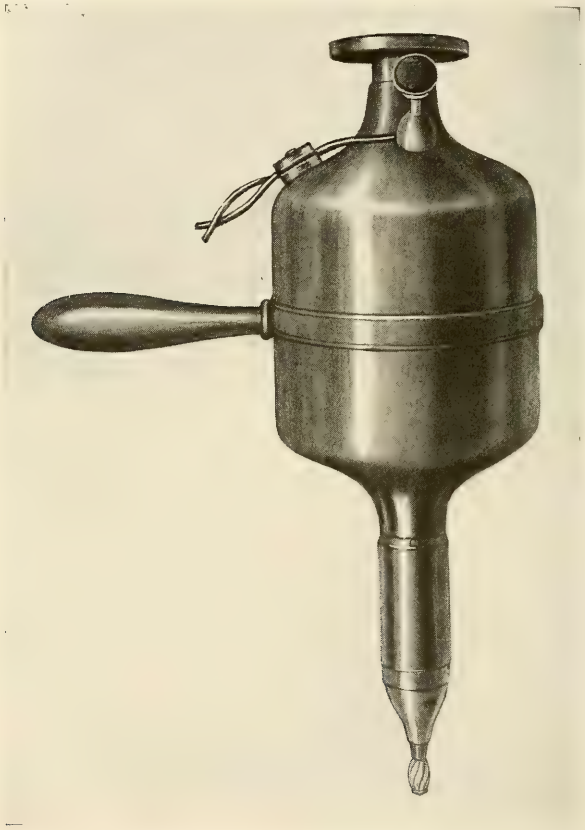

Fig. 72.—Surgical Electric Motor.

This motor is covered with a casing which is removable and sterilizable. The handle gives the operator better control of the instrument and prevents its rotation. The motor is here shown fitted with a burr. (From Warbasse's "Surgical Treatment.")

branch of surgery have been made. While these contributions have not introduced new principles, they have confirmed the value of accepted methods and established some useful modifications.

* Supplementary to Chapter LXXIV, Vol. V, p. 732, and Chapter CXLIV, Vol. VI, p. 898.

Instruments.—Electric Motor.—For purposes of drilling and sawing the electric motor with a sterilizable cover has become established in general use. This has proved most useful in bone-grafting and other plastic operations. It is used to drive such instruments as the circular saw, the drill, burr, and trephine (Figs. 72, 73).

Cheek Retractor.—For securing access to the interior of the mouth without incision a cheek retractor is necessary. A most useful instrument for this purpose is one which W. W. Keen illustrates in his book

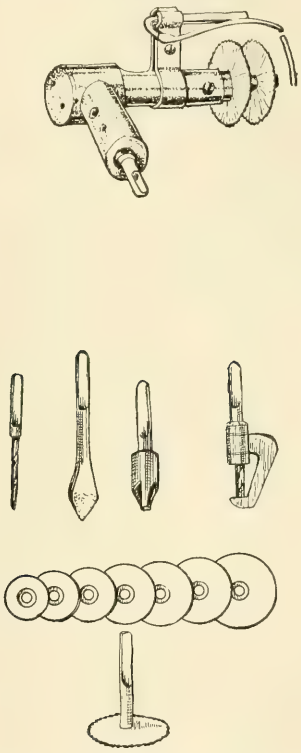

FIG. 73.—BONE-CUTTING APPARATUS.

Drills, burrs, trephines, and circular saws used with electric motor. The double saw for cutting parallel lines for bone-grafting is shown at the upper aspect of the picture. This is operated by the electric motor through the right-angle attachment. Note tube to connect with water pipe to play a stream of water on the saws when in operation. The washers arranged above the bottom circular saw are to regulate the depth to which the saw shall cut. (From Warbasse's "Surgical Treatment.")

on Surgical Operations on President Cleveland in 1893.[1] This retractor made it possible to remove the entire left upper jaw from the first bicuspid nearly up to the middle line for sarcoma intra-orally, so that there was no external scar. This retractor, as Dr. Keen points out, is not new, but should be better known in surgery (Fig. 74)

Operations for Osteomyelitis.—Acute Osteomyelitis.—This is a condition in which the importance of the operative treatment ought to receive greater attention. The disease is not new, but the treatment needs to be modernized.

Operation in the acute state of osteomyelitis, during the first forty-eight hours, is the period of choice whenever possible. If operation can be done at this early stage the extensive destruction of bone, which so commonly results from this disease, can be averted. If the disease is still confined to the medulla, the surgeon should be guided by the pain in selecting the place to open the bone. A small painful area will usually be found by making pressure on the bone. The limb should be emptied of blood by elevation, and the elastic bandage applied, jumping over the diseased region without compressing it, and the hemostatic constriction made well above the seat of disease. A longitudinal incision should be made, the soft tissues and periosteum retracted, and the bone trephined at the tender spot. The medulla will be found infiltrated with pus. All that is required in this condition is to insert a drain in the opening, close the rest of the wound, and apply a copious dressing (Fig. 75).

If periosteitis has developed, the bone should be exposed at that point. The periosteum should be incised to the full extent of the inflammation. It should carefully be stripped up from the bone, held apart by retractors, and the bone examined for openings through which

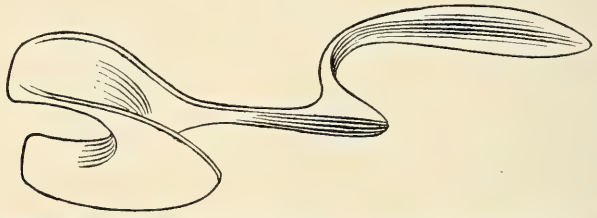

Fig. 74.—The French Cheek Retractor Used in the Operation on President Cleveland in 1893.

pus is escaping from the marrow cavity. If an opening is found, the trephine or chisel should be applied at this place and the medullary cavity opened. If no fistulous opening is discovered, the medullary cavity should be opened at the most convenient point in the wound.

The medulla will be found inflamed and infiltrated with pus, but not destroyed, when operation is done early enough. This inflamed medulla should not be cureted or disturbed. The simple opening for drainage of the bone canal should suffice to check the progress of the disease; and the earlier this operation is performed the less will be the subsequent destruction of bone. Upon opening the canal, however, if broken-down and disintegrated medulla is discovered, or if the medulla is found to be displaced by pus, the bone covering this area should be removed with the chisel up to the point where simply inflamed, but not disintegrated, medulla is found (Fig. 76).

The old practice of cureting out inflamed medulla cannot be condemned too strongly. The disease is a cellulitis, and the object of the operation should be to save as much tissue as possible. Free drainage, just as in cellulitis in other tissues, and not the removal of the inflamed structures, is the important thing. This medullary tissue plays too

important a rôle in the economy of the bone to be sacrificed. Its friability and the ease with which it can be removed are no criteria of its importance. It should always be borne in mind that the vitality of the bone depends upon the periosteum and the medulla, and that the bone does not perish until these become separated from it. All operations for osteomyelitis should aim to preserve these two tissues, and to do so the surgeon should sacrifice as much bone as is necessary. Inflammatory products, confined under the unyielding bone, rapidly de-

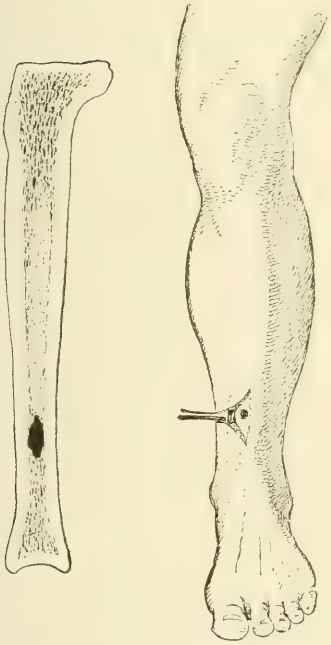

FIG. 75.—EARLY OPERATION FOR ACUTE OSTEOMYELITIS.

Note simple incision and trephine opening of medullary space. This is all that is required in first thirty-six hours. The disease is still localized. The patient may be expected to recover without further complications.

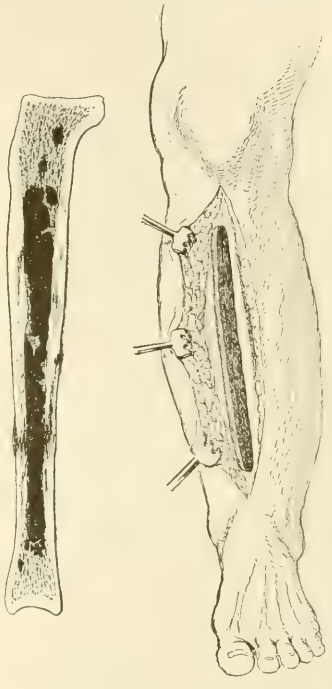

FIG. 76.—OPERATION FOR ACUTE OSTEOMYELITIS A FEW DAYS LATER.

The shaft has been destroyed by the disease, the leg is edematous and infiltrated with inflammatory products, metastases are present in other bones, an infected clot has formed in the heart—all this while the patient was being treated with poultices, internal medication, and vaccines. Recovery is doubtful.

(From" Warbasse's Surgical Treatment.")

stroy the medulla; and under the periosteum, until evacuated, they rapidly strip it up from the bone. The cavity of the bone having been opened, a rubber drainage-tube or a very loose capillary drain is inserted through the soft tissues down to the bone, and the wound left open. If a large excavation of bone has been made, the cavity should be packed with gauze, partially closed by suture, and covered with a copious, moist, absorbent dressing.

Operations for this disease may be done in two stages: the first for drainage of the medulla, as soon as the diagnosis is made; the second

during the subacute stage, for the removal of necrotic bone. If the first is done early enough, the second will not be necessary. There are few operations in surgery in which prompt action is more imperative. The infection is developing in unyielding tissue; the swelling cannot be accommodated; occlusion of vessels with infected clots, necrosis of bone, and metastatic infections result unless prompt relief is secured.

This is the disease which is so commonly diagnosed as "rheumatism," arthritis, and later as erysipelas, abscess, or typhoid, and denied the prompt treatment which would prevent metastatic abscesses and infective embolism. There is no single disease which is a greater reproach to the medical profession. The tardiness of the general practitioner to secure prompt relief in acute osteomyelitis is inexcusable. The recognition of the disease is easy, the treatment is simple. Operation at the hands of the most unskilful is not so dangerous as the disease when left unoperated upon. Many children are crippled and die of this disease. Too rarely does the general practitioner recognize acute osteomyelitis in its *first stage*, and secure immediate surgical relief without wasting precious time with palliative measures while destruction of the bone and general infection make rapid progress.[4]

Filling of Chronic Bone Cavities.—The methods for the treatment of cavities which remain after osteomyelitis are satisfactory in most cases. During the past two years "bipp" has been employed in these cases with a high degree of success.

Filling with "bipp" is used in cavities which can be entirely covered. If the excavation is open, if possible it should be covered by a sliding flap of skin, fat, periosteum, and bone. The sealed cavity thus created is filled with bipp paste, with good results.[2]

Chronic bone fistula may advantageously be treated with *bipp paste.* The diseased bone-tract should be cleaned out and freshened to remove dead particles and the infected layer. Bleeding should be stopped. The walls of the bone should then be rubbed with the paste. Stoney[3] recommends a modified paste composed of iodoform 2 parts, bismuth 1 part, and vaselin 12 parts. Finally the cavity is filled with this mixture. The mouth of the fistula is closed by a plastic suture to seal it completely. If it seems best to leave open the mouth of the fistula, then instead of filling the fistula with paste it should be packed tightly with gauze impregnated with bipp. This plug should be left in for forty-eight hours, and then removed and the cavity filled with the paste. The paste filling should not be introduced until bleeding is absolutely checked. Morison himself has warned surgeons that *all excess* of bipp must be removed, leaving only a thin covering of the paste, lest bismuth- or iodoform-poisoning should follow. A number of such cases have been reported from a neglect of the caution.

Instillation of hypochlorite solution has given excellent results in the treatment of these cases of chronic bone fistula. The fluid is applied just as in infected wounds of the soft parts.

Organic tissues for purposes of filling bone cavities are employed with much success. Such tissues may be *living tissues* which do not

lose their cellular character or identity after transplantation, but receive a blood-supply from a new source and continue to live. Also organic substances are employed which are penetrated by new cells, absorbed, and disappear, but during the process serve as a scaffolding into which new bone develops.

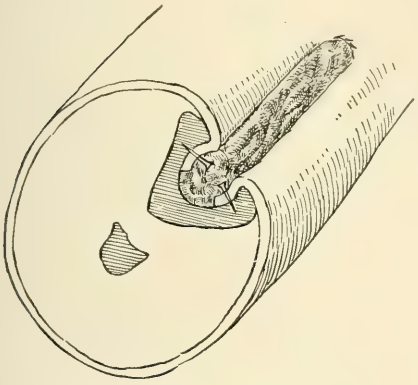

FIG. 77.—OPERATION FOR OSTEOMYELITIS.
Skin turned into bone cavity, and held by nails and gauze, after the cavity has been uncovered.

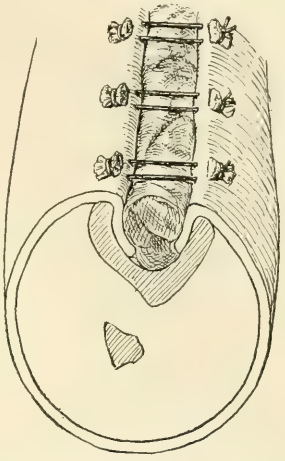

FIG. 78.—OPERATION FOR OSTEOMYELITIS.
Skin turned into bone cavity, and held by bolster sutures and gauze.

(From Warbasse's "Surgical Treatment.")

Fat offers an excellent material for filling sterile bone cavities. A flap of fatty tissue may be cut from the patient's buttock or other fatty region, and fitted into the cavity. It is especially useful in the tibia. Pieces of fat as large as 20 cm. long have been successfully implanted in bone cavities.

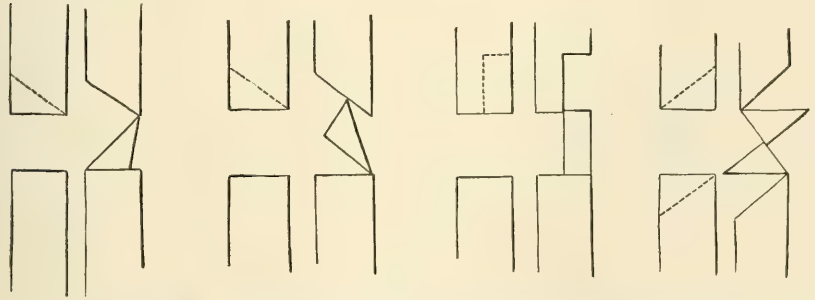

FIG. 79.—DIAGRAMS SHOWING METHODS OF LENGTHENING BONE OR FILLING DEFECTS BETWEEN BONES.
(From Warbasse's "Surgical Treatment.")

Operation in the chronic stage of osteomyelitis is well understood. After the cavity has been unroofed and sterilized, if it is not deep and the surrounding skin is in good condition, the skin may be dissected up on either side for the length of the wound and simply turned down into the bone trough. It may be held here by bone-nails and a light

gauze packing (Fig. 77). Mattress sutures are also of service (Fig. 78). Pediculate flaps may be turned in and held in place in the same

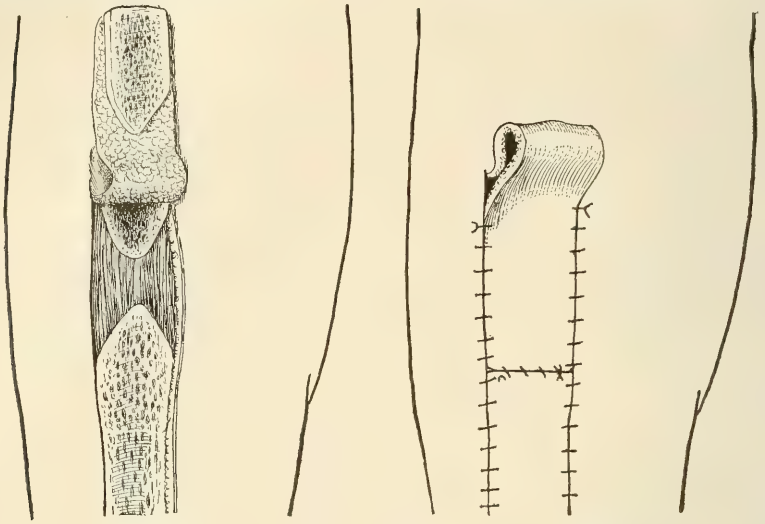

Fig. 80. Fig. 81.

Figs. 80 and 81.—Sliding Flap of Skin, Fascia, Periosteum, and Bone to Be Placed in Bony Defect.

Such a flap carrying a piece of bone may be used to bridge a gap caused by loss of bone due to fracture or osteomyelitis. The flap is placed in position in such a manner that the bone bridges the gap, where it becomes attached and in time hypertrophied. A sliding flap of skin closes the skin defect. (Fig. 80 illustrates Mueller's operation after Binnie.) (From Warbasse's "Surgical Treatment.")

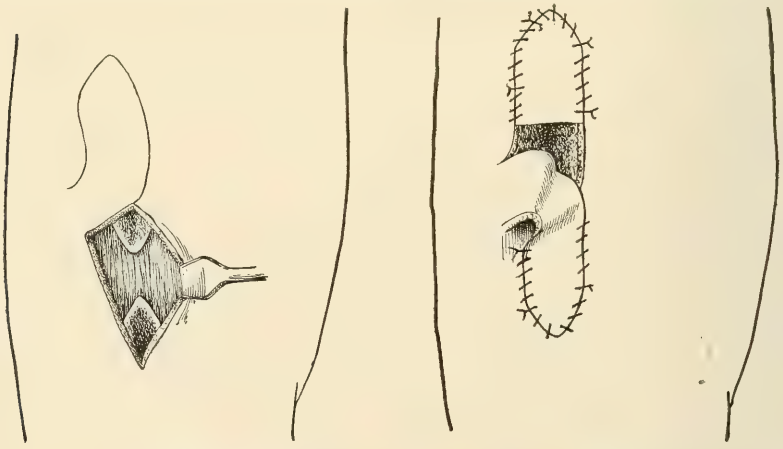

Fig. 82. Fig. 83.

Figs. 82 and 83.—Operation for Swinging an Osteogenetic Flap, Consisting of Bone and Soft Tissue, to Connect the Fragments in Old Ununited Fracture and After Loss of Bone from Osteomyelitis.

The flap is liberated with a piece of bone attached to its posterior surface. The soft tissue cut from the area into which the osteoplastic flap is to be placed is transplanted into the area from which the flap is taken. Both are sewed in position. (Mueller's Operation.) (From Warbasse's "Surgical Treatment.")

manner. In cases in which there is a large cavity it is wise not to attempt too much at one sitting. The plastic operations may be done to

advantage at intervals. Flaps for this purpose may be taken from the other leg when no other skin is available.

Operations for Loss of Bone Substance.—In cases of loss of substance following either disease or injury, any of the bone-filling methods may be used. Small gaps in bone may be filled by taking a small fragment from the ends of adjacent bone (Fig. 79). For filling the gap in old ununited fracture, or following osteomyelitis, a flap of bone may be swung in attached to a flap of soft tissue (Figs. 80–83). These are operations of Mueller, described in Binnie's Operative Surgery.

FIG. 84.—DEFECT OF TIBIA TREATED BY TURNING IN LOWER END OF FIBULA, AND SECURING BONY UNION BETWEEN THE UPPER TIBIAL SHAFT AND THE FIBULA.

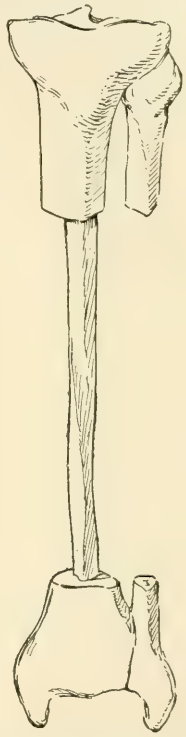

FIG. 85.—DEFECT OF TIBIA TREATED BY TRANSFERRING SECTION OF FIBULA INTO GAP.

(From Warbasse's "Surgical Treatment.")

In cases of defect of the tibia the gap may be filled by dividing the fibula and turning it into the defect. This may be done at one end of the defect or at both ends (Figs. 84, 85). The operation may be done in one stage or in two stages. The tibia may be made to rest upon the shaft of the transposed fibula (Fig. 86). Successful results are also secured by using only part of the thickness of the fibula (Fig. 87). These bone-flaps, if left attached to the adjacent fascia, are somewhat insured against necrosis. In the case of the tibia and fibula the defect in the tibia is exposed by retracting outward the tibialis anticus muscle

with the vessels and nerve, freeing them from the anterior surface of the interosseous membrane, and carrying inward the flap of fibula attached to the membrane and adjacent muscle.

Cases operated upon by the above methods show a surprising growth of the transposed bone. A segment of fibula, introduced into a tibial defect, unites as a fracture, and in the course of a year or so it will be found enlarged to the size of the tibia. The loss of the fibula does not seem to impair the function of the leg. Whatever operation is done,

FIG. 86.

FIG. 86.—TIBIA CAUSED TO UNITE WITH SHAFT OF TRANSPOSED FIBULA.

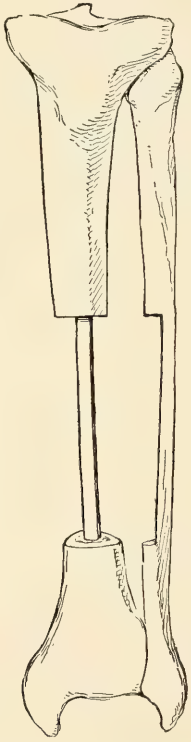

FIG. 87.

FIG. 87.—DEFECT IN TIBIA TREATED BY TRANSPOSING PART OF THICKNESS OF FIBULA.

The transposed bone in time becomes greatly enlarged.
(From Warbasse's "Surgical Treatment.")

FIG. 88.

FIG. 88.—TRANSPLANTATION OF FIBULA INTO DEFECT OF TIBIA, BY SPLITTING LOWER END OF FIBULA AND PRESERVING OUTER MALLEOLUS.

the full weight of the body cannot well be borne on either tibiofibular joint alone. Cases in which the fibula has been cut across and the upper end of the lower fibular fragment placed against the upper tibial fragment develop inversion of the foot, which must be remedied by dividing the fibula lower down and planting it against the lower segment of the tibia (Fig. 88). The weight of the body should fall through the two extremities of the tibia.

The patella may be used to fill a defect in the tibia by leaving the

transposed bone attached to a pedicle of fascia and muscle. The spine of the scapula may be introduced in a defect of the humerus. Any adjacent bone may be used in whole or in part for this purpose.

Resection of Bone for Tumors.—Resection of the lower half of the shaft of the tibia for sarcoma, leaving the lower epiphysis, is successfully done. The gap is closed by splitting longitudinally the remaining half of the shaft up into the tuberosity, turning the segment down, and fixing it in place. Only 1.5 cm. ($\frac{5}{8}$ inch) shortening has resulted from such an operation, and a strong and useful leg secured (Figs. 89, 90).

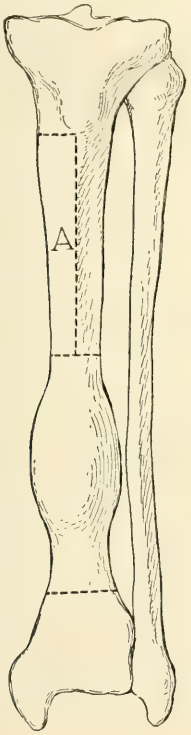

FIG. 89.

FIG. 89.—TRANSPLANTATION OF HALF OF UPPER HALF OF SHAFT OF TIBIA TO FILL DEFECT AFTER RESECTION OF LOWER HALF FOR SARCOMA.

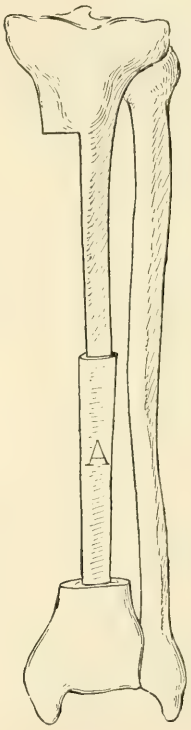

FIG. 90.

FIG. 90.—RESULT AFTER TRANSPLANTING HALF OF UPPER HALF OF TIBIA (*A*) INTO DEFECT OF SHAFT.

(From Warbasse's "Surgical Treatment.")

Excision of the diseased portion of the bone is the best surgery in many cases of malignant diseases. This is especially indicated when *early* diagnosis is made. The *x*-ray has contributed much to this end. Moreover, patients come more willingly to operation if they know that the limb is not to be sacrificed. It is difficult to persuade patients with a scarcely discernible and painless swelling to consent to amputation. The operation almost invariably is deferred. But they will consent to excision, and for this reason its results are better. An early

excision is of more value than a late amputation, for it should remove all of the local disease as completely as amputation does. If metastases have taken place, amputation offers nothing better than excision. If metatastases have not taken place, the sooner the tumor is removed, the better; and it is necessary to remove only the tumor. In doing this, if much bone has to be sacrificed, the surgeon then is confronted not with a condition that threatens the patient's life, but only the usefulness of the limb. To restore this he has all of the resources of plastic surgery; and, if he fail, the worst that can come is the removal of the useless member.

Excision of the long bones for malignant disease has been advanced to such a point that it is now a well-accepted procedure. Some surgeons advocate resection in all cases of sarcoma of bone where the disease can be excised without injury to the vessels or without removal of so much tissue that the limb is rendered useless.

Amputation is indicated when the resection necessary to remove all of the disease would leave a limb which is beyond restoration to usefulness. It is a noteworthy fact that death following operations for sarcoma of bones has not been associated with local recurrence, but with remote metastases. Operators formerly laid stress on the kind of tumor that the surgeon had to deal with. This need be given but little consideration. In all cases the aim is to remove all the growth, irrespective of the degree of malignancy, and with as little damage to the parts as possible.

In some sarcomata the disease can be cured by chiseling away the disease, and at the same time preserving the continuity of the bone; in other cases a resection of the entire thickness of the bone suffices; in others an amputation a short distance above the disease is necessary; and in extensive malignant growths involving the soft tissues as well as the bone, exarticulation at the joint above the disease is imperative. The results after resection and amputation are equally good if the tumor is confined to the bone, and almost equally bad if there is infiltration of the muscle.

Resection in preference to amputation is a great advance in operative surgery, and is not only destined to preserve limbs, but to lower the mortality of malignant disease. It is limitless in its field of application; it is applicable to all the bones of the extremities. It is not only possible to resect segments of long bones, but the whole bone may be removed and the patient left in a more useful state than he could be after amputation. This is illustrated in the case of a woman who earned her livelihood by needlework. The humerus was removed and the ulna was articulated to the shoulder. The result was a functioning hand.

Osteotomy Combined with Resection of Long Bones.—A section of bone is sometimes required to be removed on account of *unequal length of parallel bones* when lengthening of the bone is not to be considered. This is the case when one femur is so much longer than the other that curvature of the spine develops or an artificial lift under the

foot is necessary, or in cases in which a leg bone or forearm bone outgrows its fellow and distorts the ankle or wrist. If, for example, it is desired to remove 5 cm. of the shaft of the femur, longitudinal incision is made at the middle of the outer aspect of the thigh from 10 to 15 cm. long, and carried down to the bone. The periosteum is elevated over 8 or 10 cm. of the bone, and the overlying soft parts separated with it. Five cm. are then measured off, and above and below these points the bone is drilled through for the passage of the wire to hold the divided ends. The wire saw is then passed, and the bone sawed obliquely in such a way that a wedge-shaped end is secured on one fragment and a wedge-shaped indentation to receive it is secured on the other (Fig. 91). The fragments are then wired, or metal plates may be screwed to the bone to hold the ends together, or a medullary plug made of the excised segment.

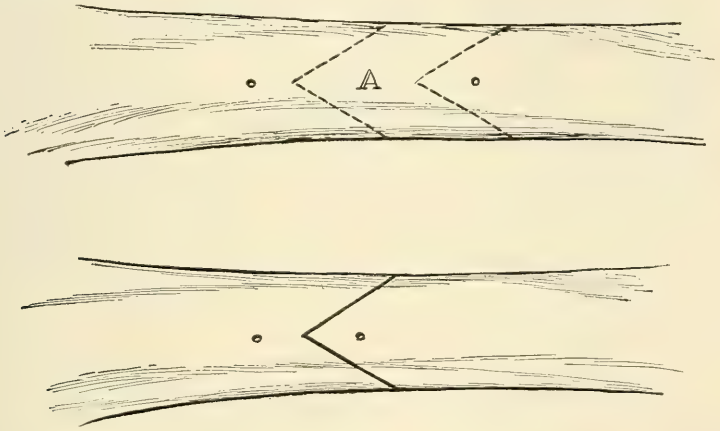

FIG. 91.—REMOVAL OF SECTION TO SHORTEN BONE.
Note that holes have been bored for wire or suture before the section (*A*) is removed. (From Warbasse's "Surgical Treatment.")

The Patella.—Removal of the patella is better than a prolonged confinement in bed or treatment with an uncertain outcome. The bone is not essential for the function of the knee-joint. By suturing the quadriceps extensor tendon to the patellar tendon practically normal extension of the knee may be obtained. The important step is that the reflected synovial lining shall be united also beneath the site of the patella. Synovial lining for this purpose is to be found in the alar ligaments hanging on either side of the patella; and the reflected synovial membrane behind the quadriceps may be brought down.

When tissue is required to strengthen the place of union between the quadriceps tendon and the patellar tendon, a flap of fascia may be turned down from the front of the thigh just above.

For Strengthening the Patella.—When operation is contemplated because of repeated refracture or inability to unite the fragments of a fractured patella, such a flap as above described may be turned down and the resection rendered unnecessary (Figs. 92, 93).

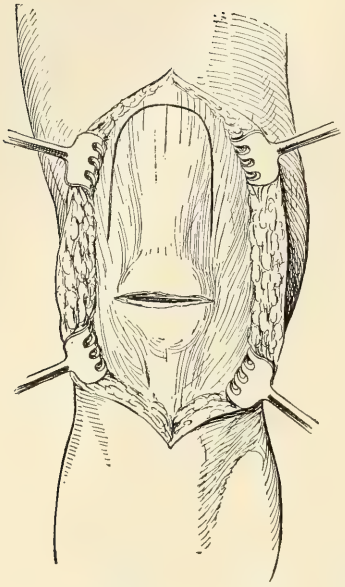

FIG. 92.—FLAP OF FASCIA TO BE TURNED DOWN TO STRENGTHEN PATELLA.

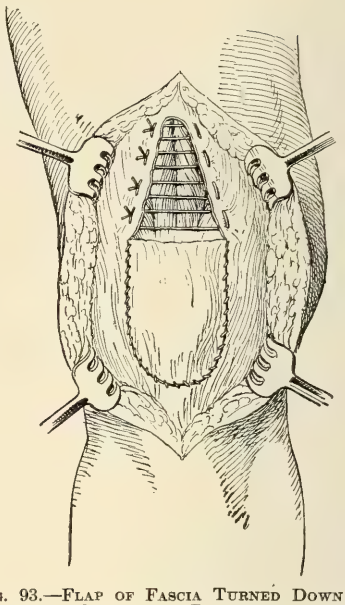

FIG. 93.—FLAP OF FASCIA TURNED DOWN TO STRENGTHEN PATELLA.

This operation is done for refracture and for weak patella. The fascia is sewed over the patella and the resulting defect partially sutured.

(From Warbasse's "Surgical Treatment.")

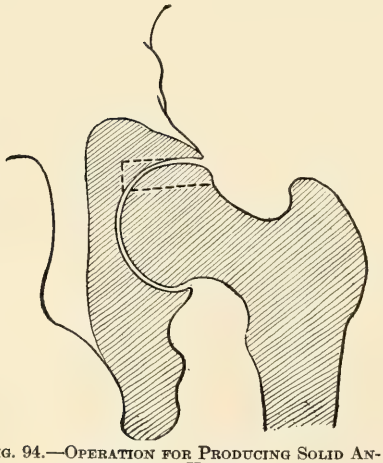

FIG. 94.—OPERATION FOR PRODUCING SOLID ANKYLOSIS OF HIP-JOINT.

The upper part of the head of the femur and the wall of the acetabulum are to be removed with chisel and curet. (After Albee.)

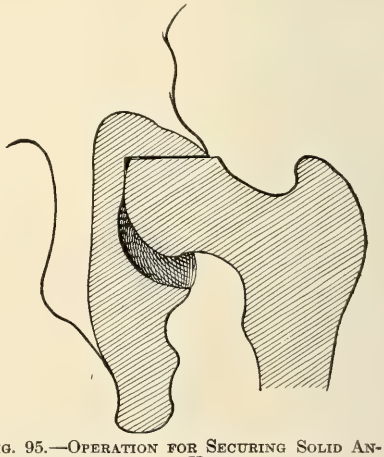

FIG. 95.—OPERATION FOR SECURING SOLID ANKYLOSIS OF HIP-JOINT.

Bone has been removed from head and acetabulum. Note that head rides upward out of socket and some shortening results. (After Albee.)

(From Warbasse's "Surgical Treatment.")

Arthrodesis of Hip.—In **osteo-arthritis** and **paralytic relaxation of the hip** the joint may be reached by an anterior incision. The capsule is opened. One-third of the upper part of the head of the femur is

removed with a thin chisel. The roof of the acetabulum is converted into a flat surface by means of a chisel and curet. The limb is immobilized in a plaster-of-Paris splint from the chest to the toes. The bone should be so removed as to give slight abduction (Figs. 94, 95).

For Opening the Knee-joint.—For the purpose of securing the best possible access to all of the structures of the knee-joint the *U-shaped incision* has many advantages, and some disadvantages. If the operation is done for infection, or if, for any other reason, the flap cannot be sewed back in place, the ligaments become adherent and are replaced with difficulty.

In uninfected cases a better result is secured by carrying the incision below the tubercle of the tibia. The tubercle with its ligamentous attachment is sawed free from the tibia, and the flap turned up with

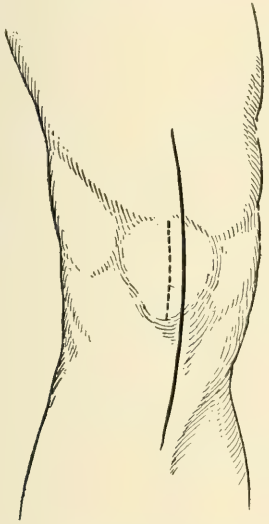

FIG. 96.—PATELLA-SPLITTING INCISION FOR EXPOSURE OF KNEE-JOINT.

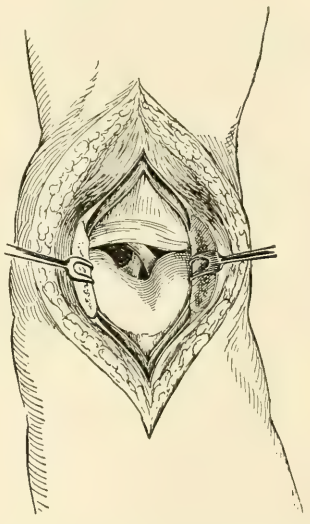

FIG. 97.—PATELLA DIVIDED VERTICALLY, RETRACTED, AND KNEE-JOINT EXPOSED.

(From Warbasse's "Surgical Treatment.")

the tubercle. At the conclusion of the operation the tubercle is reattached in place. The most simple approach is by incisions made longitudinally on either side of the patella.

A route of access which I have used with satisfaction is in the middle line of the leg, *bisecting the patella*. The incision should begin in the midline of the thigh 6 or 7 cm. above the patella, and pass downward across the middle of the patella and the patellar ligament to the tubercle of the tibia. The joint is opened above the patella. The bone is sawed through evenly so that it falls apart in two lateral halves. The quadriceps muscle and the patellar ligament are split, the wound retracted, and the joint exposed (Figs. 96, 97). Through this opening operations may be done on the synovial sac, on the cartilages, on the crucial ligaments, and on intra-articular fractures of the tibia and femur.

At the conclusion of the operation the synovial sac should be closed by continuous sutures, one above and the other below the patella; the quadriceps, prepatellar, and infrapatellar ligaments should be united with a continuous suture; and the wound in the skin closed with a running suture (Figs. 98, 99).

Operations for Ankylosis.—The interposition of soft tissue flaps to cure ankylosis is the ideal operation in cases of hopeless destruction of joints. In these cases operations on any of the important joints may be done. A case of total ankylosis of both hip-joints may be restored to flexibility so that the patient can flex the thighs to a right angle.

Transplanted soft tissues are the most satisfactory substances for these purposes, especially fascia and fatty tissue. They should be

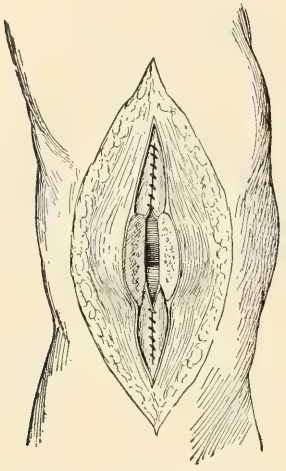

FIG. 98.—CLOSURE OF WOUND AFTER PATELLA-SPLITTING OPERATION FOR EXPOSURE OF KNEE-JOINT.

The synovial sac is closed with continuous sutures above and below the patella.

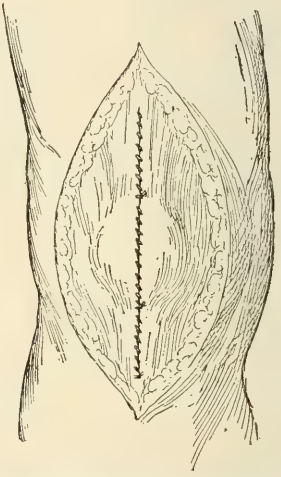

FIG. 99.—PREPATELLAR FASCIA SUTURED, UNITING THE TWO HALVES OF THE PATELLA.

The skin wound should be closed over all. Instead of a median skin incision in this operation the skin incision may be curved laterally, thus turning aside a crescentic flap. This places the skin wound at one side and separates it from that of the patella.

(From Warbasse's "Surgical Treatment.")

taken preferably from the patient's own body, but not necessarily from the region of the joint. The employment of omentum for the same purpose should be borne in mind. Whatever soft tissue is used, a sufficient thickness must be interposed to permit the formation of a joint sac within its structures, and this cannot take place if the tissue is thin.

For general purposes tissue is best secured from the outer side of the thigh. A longitudinal incision should be made through the skin only—not through the subcutaneous fatty layer. The skin alone should be dissected free by undercutting and retracting, and an area of superficial fatty fascia exposed. The flap is then cut out. It should involve the subcutaneous fat and the superficial layer of the fascia lata. The fat should not be disconnected from the fascia upon which it lies. The

flap should be handled with the utmost gentleness (Fig. 100). The removed flap is then transferred to the joint, and the skin closed over the exposed muscle.

Arthroplasty for Ankylosis of the Temporomaxillary Joint.—The incision best adapted in this operation is L shaped. The vertical arm lies in front of the ear, is in a line with the posterior border of the ramus of the lower jaw, and extends from the upper border of the zygoma 4 cm. upward. This is joined by a horizontal incision 2 cm. long which lies along the upper border of the zygoma.

The scalp is dissected free over the triangle marked out, and also below the zygoma. The wound is then deepened below the zygoma and the neck of the jaw exposed. The neck of the jaw bone is freely

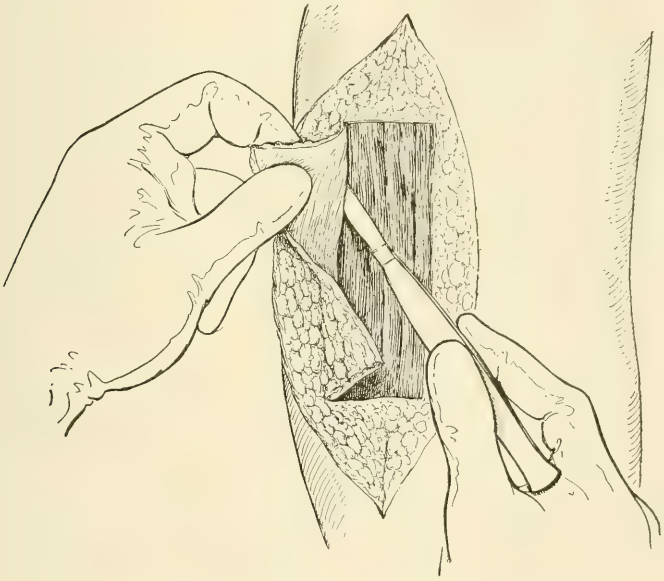

Fig. 100.—Cutting Fascia Lata with Superficial Fatty Fascia from Outer Side of Thigh for Transplantation. (From Warbasse's "Surgical Treatment.")

isolated. Two curved retractors are useful for this purpose with the special object of protecting the internal maxillary artery which lies against the inner side of the neck. If it is opened, it should be ligated at the bifurcation of the external carotid. A wire saw is passed around the neck and it is divided. The head is not removed. If bony ankylosis holds the head, about 1 cm. ($\frac{1}{3}$ inch) should be resected from the neck. The lower jaw can be freely moved as soon as the bone is divided. A flap of fat and temporal fascia, having the shape of an inverted U is turned down outside of the zygoma (Fig. 101) and its free end tucked in the bony gap below the head, and fixed by sutures on either side to the connective tissue and periosteum (Fig. 102). The wound is closed without drainage. A block of wood is inserted between the back teeth on the diseased side, and the jaw kept immobilized for

two weeks while the flap heals in place. This prevents pressure necrosis of the flap. Mastication should be begun not sooner than two weeks after the operation.

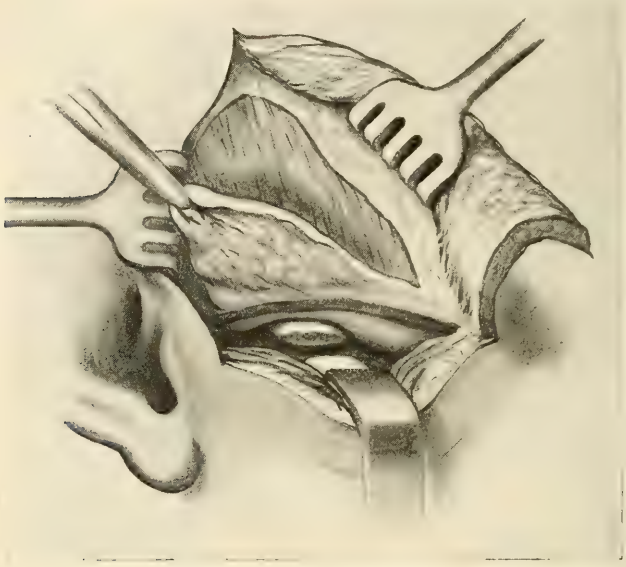

Fig. 101.—Flap of Temporal Fascia and Fat Freed for Insertion in Bony Gap. (From Warbasse's "Surgical Treatment.")

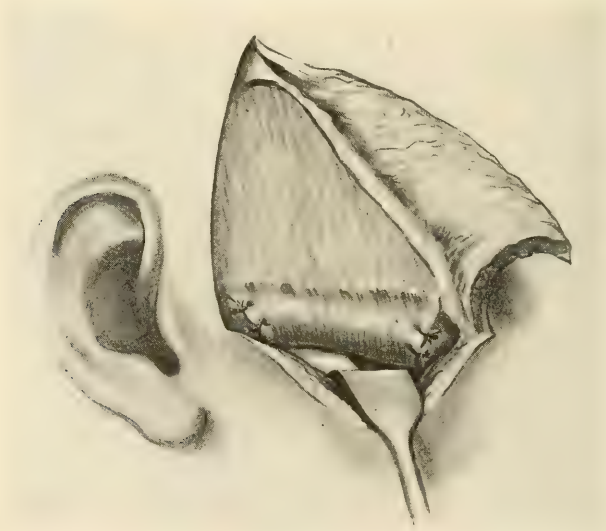

Fig. 102.—Flap Secured in Position in the Bony Interval Below the Head of the Lower Jaw. (From Warbasse's "Surgical Treatment.")

Arthroplasty for ankylosis of the elbow is done by the interposition of soft tissue. The arm should be rendered ischemic by the rubber

bandage. The joint was formerly exposed by a long posterior incision, extending from the middle of the upper arm to a point below the olecranon. A better operation is by making two incisions, one on either side of the joint about 1.3 cm. from the olecranon. The ulnar nerve should *always* be dissected free, and protected during the operation. The incisions are 15 cm. long and extend through the skin and superficial fascia. Usually the olecranon can be chiseled free from the humerus. The head of the radius sometimes is adherent and needs to be detached from the humerus. The olecranon need be divided and turned up only in exceptional cases. Rarely the lower end of the humerus must be sawed off. The ends of the bones are smoothed off,

FIG. 103.—ARTHROPLASTY OF ELBOW.

Showing bones separated and flap of fatty fascia detached and ready to place between the bones. There is an incision on either side of the joint, and flaps are turned in on either side.

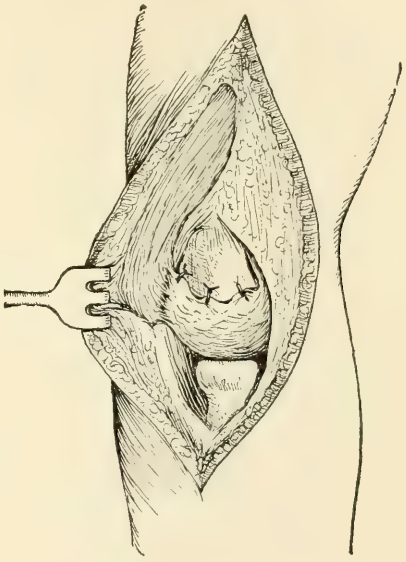

FIG. 104.—ARTHROPLASTY OF ELBOW.

Flap has been placed between the bones and sutured.

(From Warbasse's "Surgical Treatment.")

and the joint made perfectly free and movable. One flap of fascia and fat is taken from the inner side of the arm and one from the outer side. The bases of the flaps are upward. These two flaps are turned in over the end of the humerus and arm bones and sutured. Each should be long enough to be drawn through the joint and broad enough to cover all of the exposed bone (Figs. 103, 104).

Operation by a curved posterior incision gives the best exposure for division of the olecranon. The back of the joint is exposed by an inverted U-shaped incision. The ulnar nerve is dissected free and protected by gauze. The olecranon is divided transversely opposite the joint. If the olecranon is adherent to the humerus, the lower end of the humerus is removed with the upper part of the olecranon. If the

tip of the olecranon can be saved, it should be left attached. Whatever is necessary to separate the bones is done. The lower end of the humerus is rounded, and free mobility secured. A flap of fascia with the overlying fatty tissue may be dissected from the back of the arm, or it may be taken from the outer side of the thigh. The piece of fascia to be used should be 10 by 13 cm. in size. It should be dissected free and removed. This piece of fascia is removed with a layer of overlying fat attached to it. The fascia is placed over the lower end of the humerus, fat side down. It is sutured to the anterior part of the capsule and then to the posterior part with a continuous catgut suture

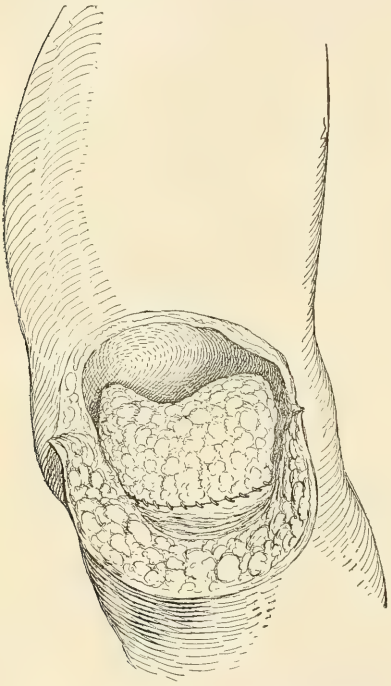

FIG. 105.—GRAFT OF FASCIA SUTURED OVER LOWER END OF HUMERUS.

The fatty surface is outward and so placed as to articulate with the radius and ulna.

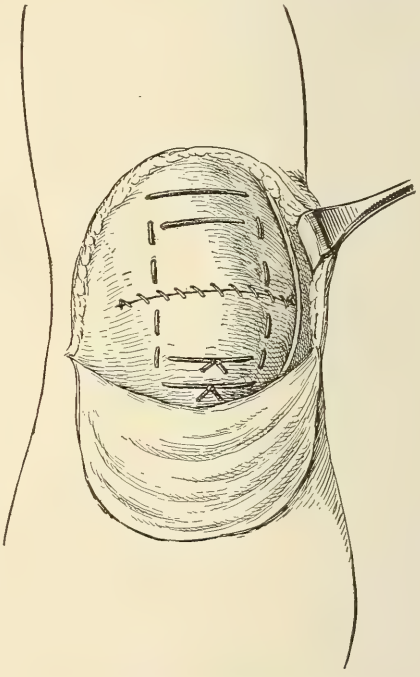

FIG. 106.—OLECRANON UNITED BY STRONG SUTURES AND JOINT CLOSED.

The ulnar nerve is seen at the side, dissected free and uninjured.

(From Warbasse's "Surgical Treatment.")

(Fig. 105), so that it forms a smooth covering over the end of the bone. The capsule and ligaments are sutured with chromic catgut. The olecranon is sutured with kangaroo tendon or double chromic catgut (Fig. 106), and the wound closed.

Arthroplasty for ankylosis of the hip may be successfully accomplished by the interposition of fascia and connective tissue. The resisting capsule and ligaments should be divided or removed, as described for the treatment of contractions and adhesions of the soft parts. Resisting muscles should be divided or stretched. In cases of bony ankylosis of the hip, a U-shaped incision is made, embracing the great trochanter,

the base of the flap being above and measuring about 8 cm. across. The incision is begun 8 cm. above the trochanter, and extends downward 5 cm. below the trochanter, which lies in the center of the U. The incision goes through the deep fascia and down to the muscle. Or the U may rest upon the great trochanter, and be supplemented by a vertical cut below, forming the "goblet incision." This flap of skin, connective tissue, and fascia lata is turned upward. The muscle bundle which is inserted into the great trochanter from above is then split on either side and the wire saw passed beneath. The saw cuts off the great trochanter with its muscular attachments (Fig. 107). The obturator and pyriformis muscles constitute the bulk of this muscular flap, which also is turned upward, exposing the joint capsule.

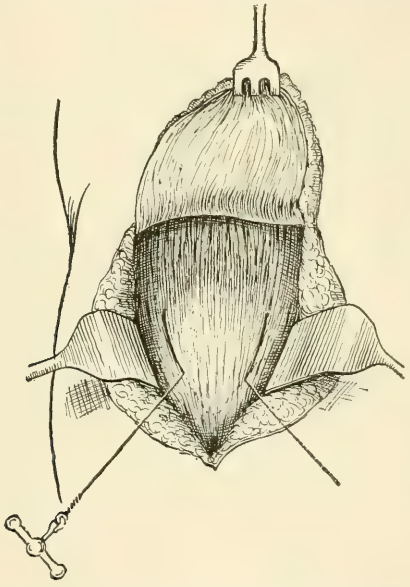

FIG. 107.—ARTHROPLASTY OF HIP.
Flap of skin, fat, and fascia lata turned up and trochanter divided with wire saw. (From Warbasse's "Surgical Treatment.")

The capsule of the joint is then opened and separated all the way round, and the head removed from the acetabulum by means of a curved chisel and fracturing force. The bone is smoothed off and the acetabulum deepened.

A flap of fascia lata in the U-shaped flap is then dissected free, fitted into the acetabulum to make a lining for it, and sutured to the capsule of the joint around the margin (Fig. 108). The free border of the flap which projects beyond the acetabulum may be sutured to the periosteum and capsule attached to the neck of the femur. The trochanter is sutured back in position and the wound closed. Tension is relieved by traction-extension with about 20 pounds. The limb is put up in the abducted position. Careful passive motions are begun about

the tenth day, and practised daily; the movements consist in lifting the leg from the bed. Abduction and adduction are begun at the end of two or three weeks. The traction should be continued for three or four weeks. Active motion is attempted from the third to the fifth week. Walking with crutches may be allowed about the fifth to the seventh week. Fairly free motion is ultimately secured.

Arthroplasty for ankylosis of the patella is often necessary following inflammation of the knee-joint or operation or injury of the patella, when the bone is found adherent to the femur, although there is no evidence of adhesion between the femur and tibia. To restore the function of the joint the patella must be freed from the femur and some

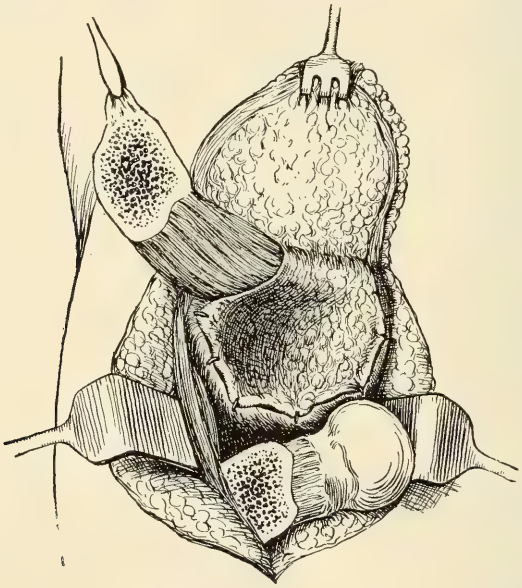

FIG. 108.—ARTHROPLASTY OF HIP.

The superficial flap has been raised, the trochanter and its attached muscles have been turned up, the joint has been opened, the head and acetabulum made ready, and a flap of fascia lata and fat dissected free from the superficial flap and sutured into the acetabulum. The next step consists in placing the head in the socket and sewing the trochanter back in place. (From Warbasse's "Surgical Treatment.")

tissue be interposed between the two bones. For this purpose an incision may be made along the outer border of the patella and continued over the vastus externus. The bones are separated, a flap of fat and fascia lata is cut from the outer region of the joint and thigh, and inverted between the bones. Two or three sutures should fix it to the opposite side. These sutures should first be attached to the edge of the flap and the needles passed between the bones and through the skin.

Another method consists in dissecting free the patella in the U-shaped flap employed for resection of the joint. The flap is turned up and the reflection of synovial membrane, which lies above the patella and be-

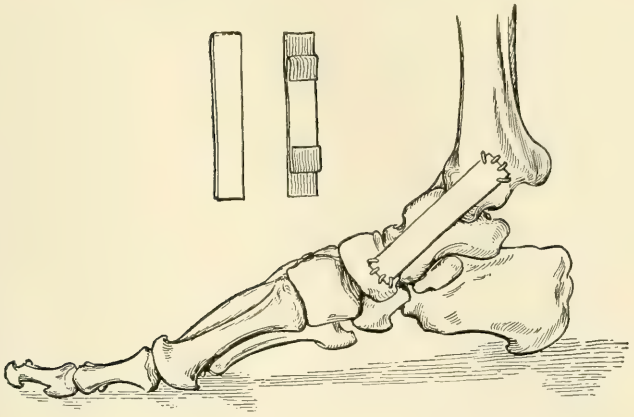

FIG. 109.—PERIOSTEAL GRAFTING TO STRENGTHEN ANKLE.

The periosteal graft, taken from the inner surface of the tibia, is folded once upon itself with the osteogenetic surfaces apposed. The ends are folded back to expose a broad surface of the osteogenetic side to be placed against the bone for attachment. (From Warbasse's "Surgical Treatment.")

FIG. 110.—OPERATION TO COMPENSATE FOR LOSS OF EPIPHYSEAL LINE OF UPPER END OF TIBIA.

The fibula with its upper epiphysis is split and moved under the remains of the tibial epiphysis.

FIG. 111.—OPERATION TO COMPENSATE FOR DESTRUCTION OF LOWER EPIPHYSEAL CARTILAGE OF TIBIA.

The fibula is split and swung across to unite with the remains of the lower tibial epiphysis.

(From Warbasse's "Surgical Treatment.")

hind the quadriceps tendon, is freed and brought down behind the patella. The flap is then replaced.

The prepatellar bursa may be interposed. A vertical incision is made along the outer side of the patella. The soft parts are dissected away from the front of the patella and the adjacent joint region. The patella is then detached from its adherence to the femur. This separation should be carried up beneath the quadriceps extensor tendon. A dissection is then made between the prepatellar skin and the sub-

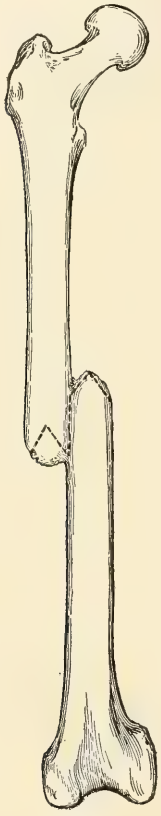

Fig. 112.

Fig. 113.

Figs. 112 and 113.—Operation to Lengthen Long Bone with Vicious Union of Old Fracture. The union is separated, the bone ends are made wedge shaped, drawn apart, and fitted together. (From Warbasse's "Surgical Treatment.")

cutaneous tissue. All of the tissues between the bone and the skin are dissected free from the skin. When this dissection has been carried a little beyond the inner edge of the patella, this mass of connective tissue, which contains the unopened prepatellar bursa, is divided above and below, and carried between the patella and femur. It is left connected internally. Its free edge is sutured to the tissues along the outer border of the patella. If the amount of tissue available is very scant, a flap of fascia may be drawn through, taken from over the

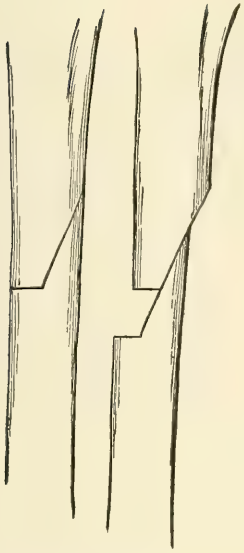

FIG. 114. FIG. 115.

FIGS. 114 AND 115.—OPERATION TO LENGTHEN LONG BONE.

The sharp end of the lower fragment is caused to pierce the medullary canal. A bone-graft may be used to maintain the separation.

FIG. 116. FIG. 117.

FIGS. 116 AND 117.—OPERATION TO LENGTHEN LONG BONE.

The apex of the lower fragment is caught in a notch made in the upper fragment.

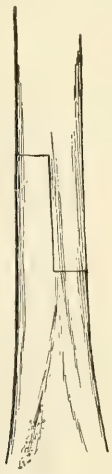

FIG. 118.—OPERATION TO LENGTHEN BONE.
Showing Z incision made with saw.

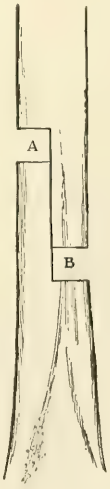

FIG. 119.—OPERATION TO LENGTHEN BONE.
Blocks of bone cut from the tibia or elsewhere are inserted at *A* and *B*.

(From Warbasse's "Surgical Treatment.")

vastus externus. The wound is closed. After healing, passive motion should be inaugurated.

Operations to Strengthen Weak Joints.—Joints which have become weak or loose from injury or disease, causing rupture or relaxation of ligaments, may be strengthened by shortening the relaxed ligament by suturing it, by folding an elongated ligament, or by implantation of fascia, tendon, or other strong tissue. Fascia from the front of the quadriceps muscle is turned down to strengthen a weak patella (Figs. 92, 93). A strip of periosteum serves admirably. A piece of periosteum, twice the width required, may be cut from the internal surface of the tibia or from a rib, folded once upon itself, osteogenetic layer inside, and then sewed to the bone on either side of the joint in the position at which it is desired that motion should be checked (Fig. 109). The osteogenetic layer should be turned back on either end so that it shall lie against the bone to which it is desired that it should become attached. This is the method of M. Katzenstein.

Operations to Compensate for the Loss of an Epiphysis.—In a growing child the loss of an epiphyseal center in the leg or forearm means distortion, as the growth of the other bone continues. The loss of either epiphysis in the tibia or fibula may be supplied by taking half of the epiphysis of the adjacent bone. This is done by splitting the bone lengthwise and transplanting one-half into the defect. The bone is split up as far as is necessary to give a splinter or brace for the defective bone. The split-off piece is left attached to its parent bone at one end. Later a plastic may be done and the detachment completed by swinging it across to fill completely the gap of bony deficiency (Figs. 110, 111). This principle is applicable in the tibia, fibula, radius, and ulna.

Operations to Lengthen Bone.—These operations are usually required in the treatment of old fractures after healing with overriding. They may be done to equalize the lengths of bones or to increase height. After dividing the bone and separating the fractured region from its soft tissues, strong traction may be applied to give the desired separation. Screws, pegs, plates, or catgut ligatures may be required to hold the fragments (Figs. 112–119).

THE TECHNIC OF BONE-GRAFTING AND TRANSPLANTATION

Transplantation of bone or parts of bone, which have been detached from their vital connections, represents the most successful employment of plastic operations for filling defects of bone. Bone-grafting is useful also in securing ankylosis of joints, in changing the contour of bones, in uniting fractures, in cosmetic surgery, and in many other fields of surgery where a transplanted body may be useful.

Filling bone defects is one of the most useful applications. The defect to be filled may be the result of osteomyelitis, tuberculosis, resection for tumor, fracture, or certain diseases. Wherever bony tissue is missing it may be supplied from other sources. The best results are secured by taking the piece of bone from the patient himself at the time of operation. This gives a fresh warm graft, without the danger of introducing an unknown constitutional infection or imposing an

operation on any one else. The graft should be cut of the size and shape desired, and transferred immediately to its new bed.

If a short time must intervene it should be kept in warm normal salt solution. If the graft must be kept for several hours or days, it is best to keep it in sterile vaselin. This prevents drying. The graft should be kept in a jar of vaselin in cold storage of a temperature of 4° or 5° C. (40° F.).

The field of operation should be prepared as for plastic operations with flaps. The surgeon who cannot command the essential principles of aseptic surgery should not attempt these operations. Periosteum should be preserved. If the defect to be filled does not involve the whole thickness of the bone, but represents only a cavity, rough bone should be opposed to rough bone, and periosteum should be placed outside. There is no harm in burying periosteum in bone, but it is desirable, though not necessary, that superficial surface should be provided with periosteum.

The bone to be transplanted should be denuded of all soft tissues. Periosteum should be left on the graft. If possible, the graft should be cut out in the size and shape needed, so that trimming is not necessary after it is removed. For transplantation of long bone from the patient himself, the fibula, all of which may be used, and parts of the tibial shaft are most available. The circular saw driven by an electric engine is best for removing the bone. The defect should be made ready, the wound covered with towels, the graft separated, and without any further treatment and with as little handling as possible placed at once into its new bed.

For holding grafts into total defects, simple suturing of the surrounding soft parts usually suffices. In some cases, fixation by pins, dowels or rings, such as are used for fixing fractures, may be required. Usually such apparatus may be dispensed with by cutting the ends of the bone in such a way as to make them self-retaining. The wound should be closed tightly throughout, fascia and muscles being replaced to support the graft. Drainage is rarely to be used. If the defect is a total one, the limb should be treated as a fracture from that time on.

In all of these operations sterilization with chlorin or iodin is at present the best protection against infection. Only gloved hands should participate in the operation, and these should rarely touch the bone and wound. Sponging manipulations should be done through the interposition of instruments as much as possible. The patient's own tibia furnishes the most useful graft material. When holes are needed in the graft, it is best that they be bored before the bone is separated. Small chips of bone should not be wasted. They should be placed about the graft if there is any unfilled space, or used to fill the defect in the tibia.

When bone from another person is used, the transfer is best made at the same time the bone is removed. Bone is furnished by parts which have required to be amputated, or from the recently dead, provided no infective condition exists in the source of the graft which

might be inimical to the patient. The two operations are sometimes done at different places, and the transplant wrapped in a warm towel, wet with salt solution, placed in a protecting envelope, and carried to the patient.

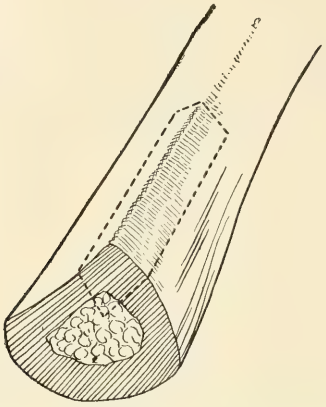

Fig. 120.—Manner of Cutting Quadrangular Graft from Crest of Tibia, Having Periosteum on Two Sides. (From Warbasse's "Surgical Treatment.")

As much as 14 cm. of femur from an amputated thigh have been successfully implanted in another patient.

Fig. 121.—Method of Securing a Curved Graft from the Inner Surface of the Tibia. (From Warbasse's "Surgical Treatment.")

Tibial Grafts.—The most accessible and useful source of grafts is the lower three-fourths of the patient's tibia. The antero-internal sur-

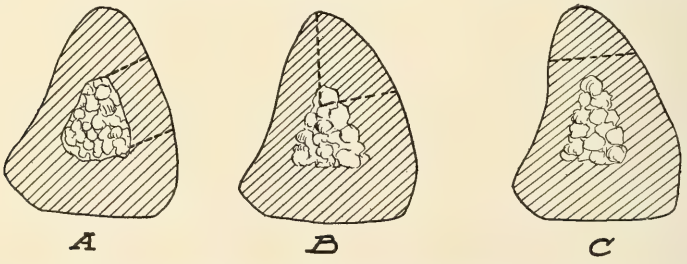

Fig. 122.—Methods of Cutting Bone-grafts.
Showing graft involving whole thickness of cortex of tibia (*A*), graft with but little marrow surface (*B*), and graft not involving medullary canal (*C*). (From Warbasse's "Surgical Treatment.")

face is most accessible. The shin or crest of the tibia gives the strongest graft. It furnishes a right angle, and provides a graft with periosteum on two sides (Fig. 120). Grafts of various shapes and sizes

may be cut from the flat surface (Fig. 121). The whole thickness of the cortex of the bone is used (Fig. 122).

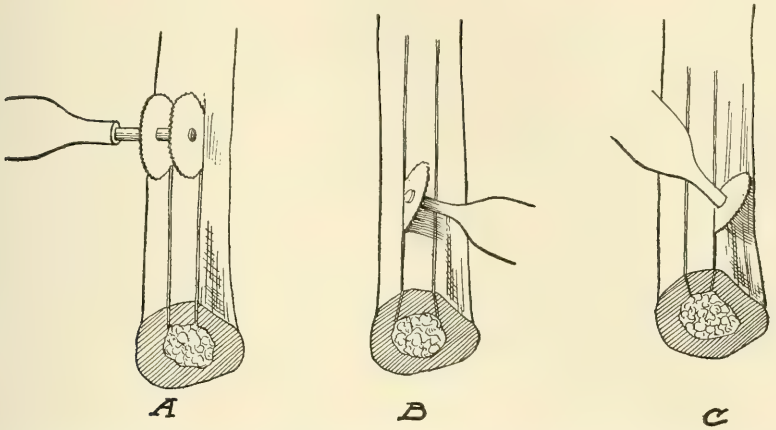

FIG. 123.—METHOD OF CUTTING GRAFTS WITH PARALLEL SIDES (*A*), WITH CENTRAL DIVERGING SIDES (*B*), AND WITH CENTRAL CONVERGING SIDES (*C*). (After Albee.) (From Warbasse's "Surgical Treatment.")

The area from which the graft is cut should be exposed by a curved incision turning back a long flap, so that when the flap is sewed back the sutures in the skin do not lie on the wound of the bone. Periosteum should be left on the graft. Grafts may be cut with parallel or oblique sides (Fig. 123). They may be cut with a saw or chisel. The circular saw is most useful. The small circular saw best serves to divide the end (Fig. 124). A triangular graft is cut by passing the saw through the whole thickness of the bone at the shin (Fig. 125).

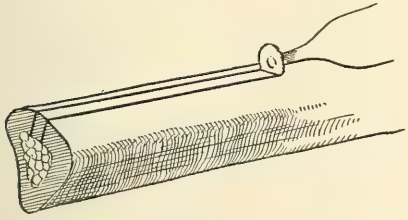

FIG. 124.—SHOWING METHOD OF CUTTING ENDS OF GRAFT WITH A SMALLER CIRCULAR SAW. (After Albee.)

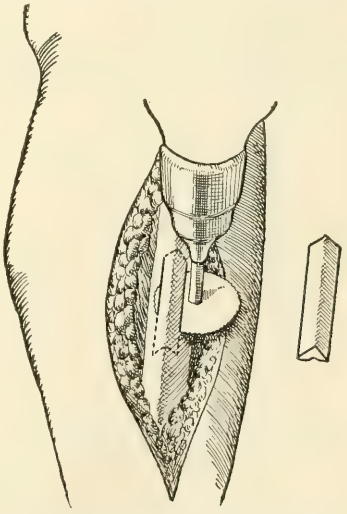

FIG. 125.—METHOD OF SECURING WEDGE-SHAPED OR PRISMATIC GRAFT FROM CREST OF TIBIA. (After Albee.)

(From Warbasse's "Surgical Treatment.")

To hold an inlay graft in a gutter the sides of the gutter should be bored and a suture of chromicized catgut or kangaroo tendon passed through. To prevent the transplant from coming out, both loops

should pass in front of it. To prevent its falling in, one loop may pass behind it and one in front of it. Usually where several sutures are applied, they may alternate, and thus prevent displacement in either direction.

Instead of using sutures, both the inlay and the sides of the gutter may be bored at several places, and small pegs of bone driven in. In many situations no special bone suturing is required, as the fascia or other soft tissue sewed over the graft holds it (Fig. 126). A most satisfactory method of fixation is by mortising. The graft is cut with a slant to its edge which prevents its escape from its bed. Pins and pegs driven into holes and canals naturally are self-retaining.

Spine.—Tuberculous Spondylitis.—*Treatment with a Graft Inlaid in the Split Spinous Processes as Applied by the Operation of Albee.*—The patient's back and leg are prepared for operation. A general anesthetic is given. The patient lies prone on the operating table. The

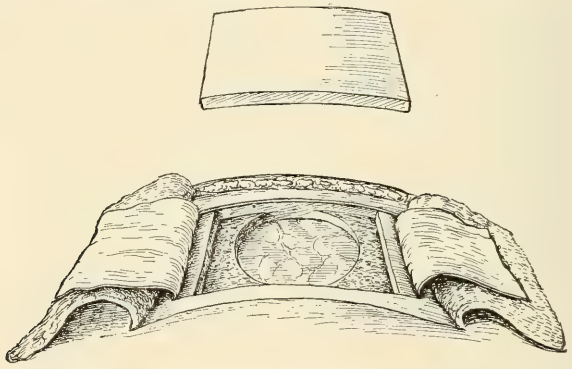

Fig. 126.—Method of Closing Defect in Skull by a Bone-graft.

Note that the scalp and periosteum are reflected; a segment is removed from the outer table only on either side of the opening. A graft of fatty fascia should be placed between the brain and the bony graft. (From Warbasse's "Surgical Treatment.")

incision to expose the spinous processes begins at the tip of the spinous process of the third vertebra above the disease; it curves to one side of the median line as a crescent, and down to the tip of the spinous process, which is the third below the disease. The skin and subcutaneous connective tissue are dissected back as a flap, exposing the spinous processes covered by their ligaments.

The supraspinous ligament is split in the median line. Then with a thin, broad, sharp osteotome the spinous processes are split exactly in the median line for a distance of 1 to 2 cm. The spines of the diseased vertebra, the two vertebræ above, and the two vertebræ below should be split. One side of the split spine should then be fractured at the bottom of the split. This should be done on the same side with all of the split spines. The gutter thus formed should be packed with a compress soaked with warm salt solution.

If there is no kyphosis, a straight graft is cut. If kyphosis is present to a considerable degree, a curved graft is useful. To determine

the size and shape of the graft, pressure is made on the kyphosis, and the curve duplicated with a flexible probe. The wound is then covered.

The patient is left in the prone position. The leg from which the graft is to be taken is flexed acutely at the knee. The graft is best taken from the lower two-thirds of the tibia, on the antero-internal surface of that bone, over an area sufficiently large to supply the graft. The flap of skin should be so placed that when the skin is sewed back in place the wound does not lie on the wound of the bone. The cutaneous flap is dissected up from the bone, leaving the periosteum on the

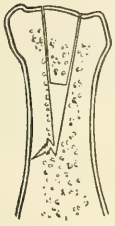

FIG. 127.

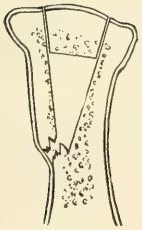

FIG. 128.

FIGS. 127 AND 128.—SHOWING METHODS OF SPLITTING AND FRACTURING SPINOUS PROCESSES TO RECEIVE GRAFT. (After Albee.)

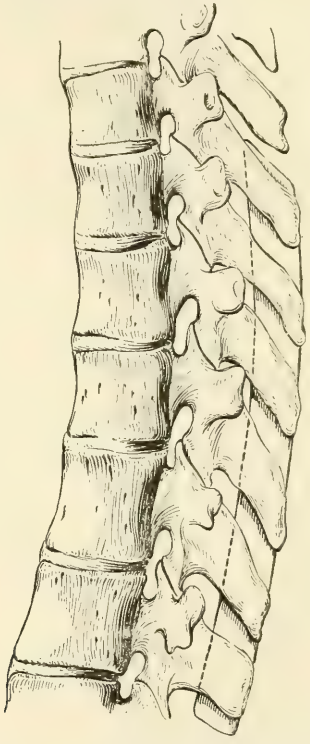

FIG. 129.—GRAFT IN PLACE IN THE SPLIT SPINOUS PROCESSES.

(From Warbasse's "Surgical Treatment.")

bone. All of the soft parts excepting the periosteum should be dissected away from the bone; the muscles are pressed back from the external surface near the crest.

The probe which represents the length and curve of the graft desired is laid on the inner surface of the tibia. The outline of the graft is marked with a scalpel which cuts through the periosteum. If a curved graft is to be cut the middle of the convexity should include the crest of the tibia to bring the strongest part of the graft where it is most needed. The graft is cut with a single circular saw. The graft should be wider on its periosteal surface.

If the kyphosis can be pressed down nearly straight, a straight graft may be cut. This should be taken from the crest of the tibia. The ends of the graft are cut transversely by means of a smaller circular saw. The graft should involve the whole thickness of the cortex of the bone down to the medullary canal. It may be freed by a chisel and lifted out with forceps, not being touched even by the gloved hand.

The gauze packing is removed from the fractured spines and the graft is deposited in the cleft (Fig. 127). The graft should include two

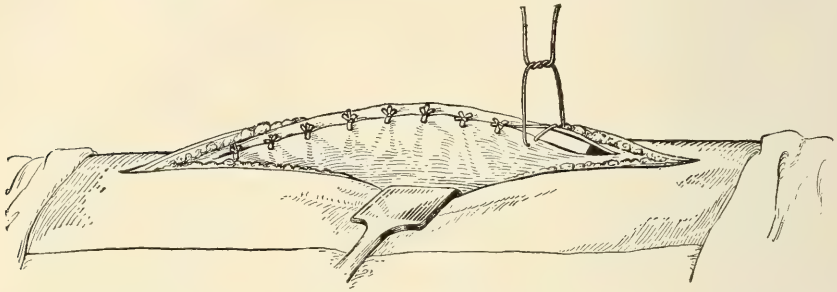

FIG. 130.—ALBEE'S METHOD OF FIXING GRAFT BY SUTURES. (From Warbasse's "Surgical Treatment.")

healthy spines above and below the disease. If a narrow graft is used, only half of the spine will need to be fractured. If a wider graft is used, half of the spine will need to be fractured and slightly displaced (Fig. 128). The graft is held in position by passing a suture of kangaroo tendon through one-half of the split supraspinous ligament close to the middle spine at one side of the gutter. The suture then passes over the middle of the graft and through the other split half of the supraspinous ligament on the opposite side. The suture is tied tightly,

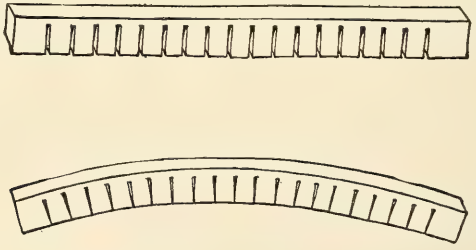

FIG. 131.—ALBEE'S METHOD OF MAKING CURVED GRAFTS BY MULTIPLE TRANSVERSE SAW CUTS TO PERMIT BENDING. (From Warbasse's "Surgical Treatment.")

drawing the split ligament over the graft. The next sutures are applied similarly at the ends. These sutures are applied above and below each spine, and in this manner the graft is buried (Figs. 129, 130).

In adults the ligaments may be so unyielding that the sutures must be placed midway between the spines in order to make the wound meet over the graft. Or it may be necessary to make an incision in the vertebral fascia on either side of the wound in order to secure apposition to cover the graft. If the angular ends of the graft are prominent,

they should be rounded off with the rongeur and the bone-chips planted in the split.

Albee made a curved graft by cutting a straight piece of bone from the tibia, and then making multiple transverse cuts three-quarters through the graft. Such a graft may be placed in position and bent with the cuts in its concavity. It is especially useful in extreme curvatures (Fig. 131).

Grafts for thus immobilizing the spine may be placed at any part. In the cervical region a much lighter graft suffices than is required lower down. Where curved grafts are not needed, but only an angulation is desired, a small wedge cut from the graft permits it to bend (Fig. 132).

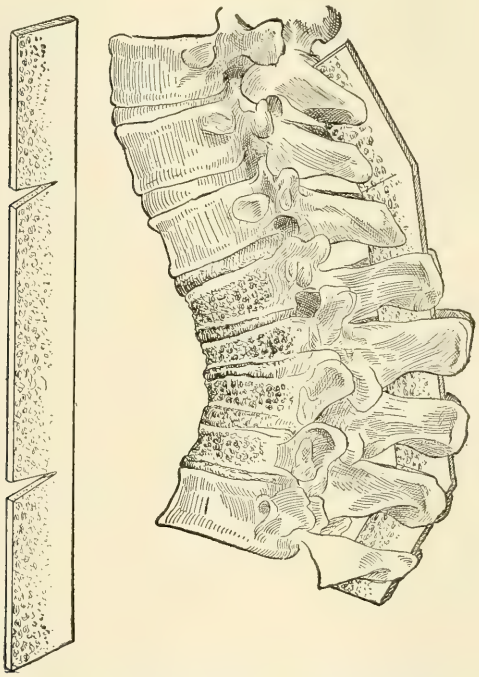

Fig. 132.—Shaping Graft to a Kyphosis After the Method of Henderson. (From Warbasse's "Surgical Treatment.")

Spinous process ankylosing is the operation devised by R. A. Hibbs. A median incision is made over the spinous processes down to the tips of the bones. The periosteum is split along the upper and lower borders of each spine and the laminæ. The periosteum and soft tissues are pressed back as far as the bases of the transverse processes. The spinous processes are then partially fractured with a chisel and bent down so that they make contact with fresh bone. At least two vertebræ above and two below the diseased bone should be operated upon. This means at least five spines (Fig. 133). The base of each remains connected at its own base and the tip comes in contact with the broken

base below. A small piece of bone is elevated from the edge of each lamina and placed across the space below it, so that it rests on the lamina below. The lateral articulations are exposed and the articular cartilage removed with a small curet.

The periosteum, which has been reflected laterally with the soft tissues, and the split supraspinous ligament are sewed together at the median line, over the processes, with kangaroo tendon or chromic catgut interrupted sutures. This operation results in a callus which binds together the vertebræ.

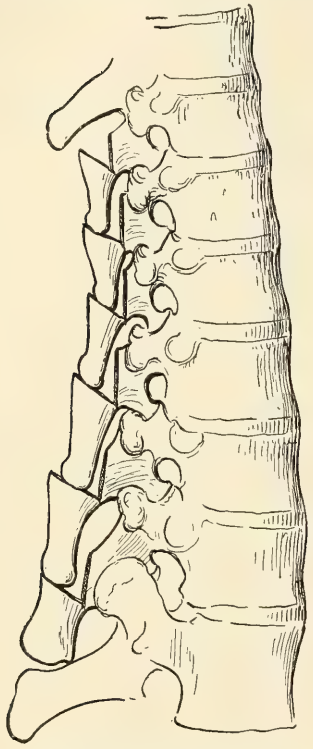

Fig. 133.—Spinous Processes Fractured and Displaced Downward to Produce Ankylosis After the Method of Hibbs. (From Warbasse's "Surgical Treatment.")

The *indications for operative treatment* of tuberculous spondylitis by these methods seem to be almost without limit. All cases at all ages in which tuberculosis is rarefying the vertebræ and causing pain and muscular spasm may be benefited by it. The earlier the operation is done, the better is the prognosis. The presence of complications, such as psoas spasm, pure tuberculous abscess, kyphosis, and paraplegia, not only do not contraindicate but call for the operation. Cases with cold abscess and sinuses seem to heal kindly. Grafts which were bathed in the pus of tuberculous abscesses have healed without exfoliation.

The indications for treatment by bone-graft and bone plastic fixation are practically the same as for all forms of fixation. Operation is applicable to all cases in which immobilization and support are needed. If the patient has enough reparative power to recover from the disease, he has enough reparative power to heal in a transplant of healthy bone or develop callus. The earlier in the disease the operation is done, the better is the reparative power and the less is the deformity. These operations offer the best hope for the prevention and correction of deformity.

The *contraindication* to this operation is the inability to secure a clean field of operation. This is rare, because the tuberculous abscess does not tend to invade the region of the spinous processes; and even though it does, bone-grafting is not contraindicated. In some cases in which such abscesses have been encountered unexpectedly the grafts have healed in place.

The *choice of operation* depends much upon the location of the disease. The spine-ankylosing operation of Hibbs is especially useful in

the middle and upper dorsal and cervical regions because of the length and shape of the spinous processes. Bone-transplant operation is to be preferred in the lower dorsal, lumbar, and sacral regions. Cases in which there is a pronounced kyphosis with separation of the spines are best treated by the bone-transplant method.

The *after-treatment* following these osteoplastic operations for spondylitis is the same for each. The wound should be closed and dressed and the patient should lie on a fracture-bed. The patient should lie quietly in the recumbent position on a hard mattress, placed on a board, for five or eight weeks. The only restraint usually required consists of a towel around the body, to which are fastened four strips of muslin, two of which lie over the shoulders, passing to each of the corners of the bed. The object of this is to prevent the patient sitting up or rolling on his side. This is not needed in the case of adults. A thick pad should be placed on each side of the spine to take pressure from the seat of operation. In cases of pronounced kyphosis the patient must be placed on his side. The plaster jacket usually is not necessary until the patient gets up, and weight bearing falls upon the spine; and even then it is not always required.

Adults usually require no restraint. If there is kyphosis, it should be protected by pads at either side of the spine. Pressure upon the wound must be avoided lest necrosis of the flap of skin occur.

If there is any question about keeping the patient quiet, a posterior plaster splint should be molded to the patient while lying prone on the operating table. This should extend from the head to the bottom of the pelvis. Or, still better, this splint may be made before the operation, a pad of gauze to imitate the dressing being introduced.

The general hygienic treatment should be continued. At the end of five or eight weeks the patient is allowed to get up. Artificial external support is usually desirable when the patient gets up. In exceptional cases support may be dispensed with. Extreme kyphosis which requires a much curved graft, and cases which have to leave the hospital before five weeks have elapsed, must always be provided with a supporting jacket for a time.

It is desirable that at least six months of postoperative convalescence should elapse before the patient takes up active work. During this time some external support is advisable. It is possible in some cases for adults to return to work in two months. Children should have outdoor life for fully a year after operation.

Hibbs preferred to apply a steel brace immediately after operation and required absolute rest in bed for eight weeks. The patients are allowed to sit up for four weeks. Walking is allowed at twelve weeks; and the brace is gradually removed at sixteen weeks.

The *results of osteoplastic treatment* after bony union has taken place are immobilization of the diseased segment of the spine and the benefits which arise from such immobilization. This is the aim of treatment by plaster-of-Paris jackets. The disease itself is not changed. For this reason immediately after the operation the patient should be

put out of doors and antituberculous measures applied. Six months should elapse before the patient resumes heavy work or active life. Children should be protected from strain for a year. Albee reports cases in which adults returned to work six and eight weeks after the operation and seemed to sustain no harm. In some cases no external support is needed during convalescence, but usually too much reliance should not be placed upon the strength of the graft. A jacket to give external support should be worn for about six months while the graft is developing callus and growing strong. If external support is not worn there is danger of increasing deformity.

Conclusions.—These operations are neither difficult nor severe. Pulmonary tuberculosis need not be regarded as a contraindication. Young patients do better than adults. External support should be used for a few months.

Paralytic Scoliosis.—In this condition, after the acute disease has gone and left the muscles paralyzed, and corsets, massage, and gymnastic exercises have done all they can, and no further improvement is attained, the spine may be fixed by a bone-graft to hold what has been secured. By the end of two years the surgeon should decide whether more may yet be gained or whether bone-graft may be used. Grafting may be done in the spinous process, as for spondylitis, or in the transverse processes. The latter is to be preferred.

A pad the size of the wound dressing is fixed over the area of operation, and a plaster-of-Paris jacket is applied. This jacket is cut off in halves by being divided on either side in the axillary line. While applying this jacket the patient should be held with the spine in a corrected position. A few days later the operation is proceeded with. A crescentic flap is turned back and the line of transverse processes exposed on the convex side at the place of the greatest curvature, six or eight are split and the outer halves of the split processes are fractured, as described for spondylitis. A graft is cut from the whole cortical thickness of the tibia and placed in the split. The patient is placed in a corrected position. The wound is sutured and dressed, and the already made plastic jacket is applied. The patient is kept recumbent in the plaster jacket six weeks. Then another plaster jacket is put on and left for ten weeks or more while the patient goes about. At the end of that time exercises should be resumed, but they must not aim to bend the spine at the site of the graft.

Spondylolisthesis.—This condition of luxation of the body of the vertebra, occurring usually in the lumbar region, is amenable to spinal grafting such as is used in spondylitis. The displacement is corrected under general anesthesia as the patient lies prone on the operating table. Lordosis may require that a pillow be placed under the abdomen. A strong graft should be used, and placed so that it embraces two vertebræ above and two below the displaced segment. This may require extending the graft upon the sacrum.

Spina Bifida.—This condition may be operated upon by placing a graft on either side of the cleft caused by the absence of laminæ and

spines. To completely cover the opening a flat piece of bone may be placed over it in the median line. The graft should be held by suturing the fascia over it.

Sacro-iliac Joint.—*Tuberculosis* may be treated by a bone-graft passing between the sacrum and ilium.

Dislocation or *relaxation* in intractable cases may be treated by placing a longitudinal graft of bone along the posterior aspect of the joint in such a manner that it lies in a denuded gutter, one side of which is ilium and the other side sacrum.

Hip.—Habitual, Paralytic, and Congenital Dislocation of the Hip-joint.—These conditions should be treated by remedying the causative disease. Manipulations and stretching contractured parts may be expected to cure most cases. Cases which do not yield to these meas-

FIG. 134.—CONDITION TO BE REMEDIED IN CONGENITAL AND PARALYTIC DISLOCATION OF HIP.

Note that the relaxation of the capsular ligament and the erosion of the upper rim of the acetabulum permit the head to ride upward out of the socket. (After Albee.)

FIG. 135.—OSTEOPLASTIC OPERATION FOR DISLOCATION OF HIP.

The tip of the great trochanter has been cut across and reflected upward with its attached muscles and the osteotome cuts the upper rim of the acetabulum. (After Albee.)

(From Warbasse's "Surgical Treatment.")

ures, and in which the head of the femur persists in riding up out of its socket (Fig. 134), may be cured by osteoplastic operation. Albee later devised an operation whereby wedges of bone from the tibia are transplanted to serve as an upper wall to the acetabulum, and thus prevent riding upward of the femoral head. Before performing such an operation all contractures which limit the mobility of the joint should be overcome by stretching gradually with weights, by forcible stretching under general anesthesia, or by division with the knife.

An incision is begun at the anterior-superior spine of the ilium and carried to the top of the great trochanter, thence it curves backward for 3 or 5 cm. toward the tuberosity of the ischium. The flap of skin and superficial fascia is dissected back and the trochanter exposed. The tip of the trochanter with its muscular attachments undisturbed

is sawed off and reflected upward. This gives a view of the upper and back parts of the capsule of the joint as far as the rim of the acetabulum.

The bone above the rim of the acetabulum is then cleared of soft tissue. With a narrow osteotome a semicircle is cut in the bone above the acetabulum close to the capsular ligament (Fig. 135). This postero-antero-superior lip of the acetabulum with its attached capsule is pried outward and downward to overhang the head of the femur and deepen the socket. The upper part of the capsular ligament which is already relaxed by the disease is still more relaxed by this step in the operation. The slack is taken up by applying a row of chromic catgut sutures (Fig. 136).

The gap in the bone above the socket is filled with bone transplant. For this purpose a triangular piece of bone is cut from the crest of the

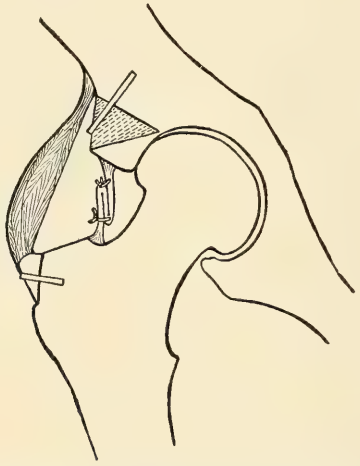

FIG. 136.—RESULT OF OSTEOPLASTIC OPERATION FOR CHRONIC UPWARD DISLOCATION OF HIP.

Note that the upper lip of the acetabulum has been turned downward; the gap has been filled with bone-graft, held with bone peg; the capsular ligament has been shortened by folding and suture; and the tip of the great trochanter with its attached muscles has been held in place on the outer aspect of the trochanter by a bone pin. (After Albee.) (From Warbasse's "Surgical Treatment.")

tibia. This should be long enough to be cut into three or four pieces which will fill the gap. Before the piece is removed from the tibia small drill holes should be bored in the graft at such positions that when it is cut into pieces each piece will have a hole. These triangular pieces are placed in the gap, and pinned by autogenous pegs cut from the tibia. The pegs should penetrate the cancellous pelvic bone for 1.5 or 2 cm. The pegs are not necessary in all cases, as the grafts may be held by the soft tissues sewed over them. The tip of the trochanter with its attached muscles is then replaced, and sewed to the soft tissues with chromic catgut or kangaroo tendon. The limb is put up in the abducted position with plaster of Paris from the chest to the toes. This is left on for six weeks, at the end of which time it is replaced by the pelvic splint. Three months after the operation the splint is removed, and passive motion and massage applied, and careful use of the limb begun.

Restoring Head of the Femur by Grafting an Astragalus.—The astragalus should be secured from the foot of another person. It may be kept in cold storage immersed in sterile vaselin at a temperature of 4° or 5° C. (40° F.). The hip-joint is best exposed by an anterior-external incision, beginning below and internal to the anterior-superior spine of the ilium, passing just below the great trochanter, and thence curving backward. The tip of the trochanter is divided with the saw, and with its muscular connections turned upward to expose the joint. The capsule is split in the direction of its fibers. The neck of the femur is trimmed to receive the new bone. The astragalus to be fitted is cut so that its articular end lies in the joint socket. A pin of bone is passed through the great trochanter and the neck and into the new head, as is done in treating fracture of the neck

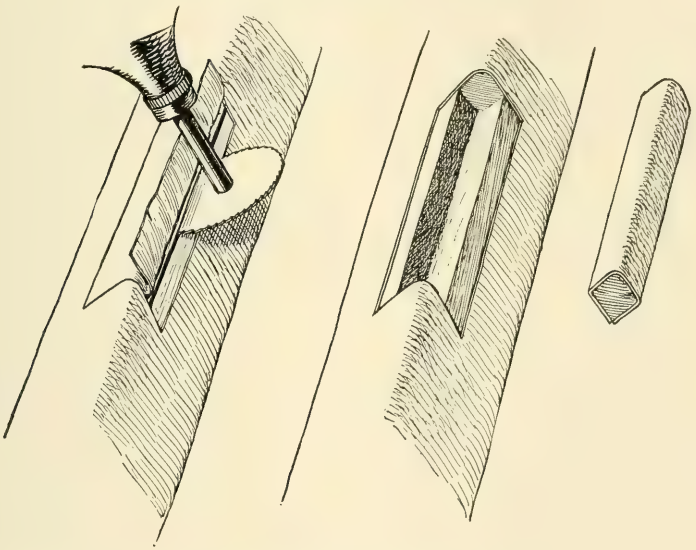

Fig. 137.—Method of Cutting Graft from Tibia in Such a Manner as to Cover It with Periosteum. (From Warbasse's "Surgical Treatment.")

of the femur. The shape of this bone adapts it admirably for this purpose, and it must often be removed for paralytic club-foot. The forward end fits the acetabulum, and the rear end is easily shaped to be fastened to the shaft of the femur by means of a bone or ivory peg or nail.

Phalanges.—Transplantation of bone into the *finger phalanges* has been successfully practised to restore the loss after tuberculosis or osteomyelitis. New bone may be secured by taking a toe phalanx. When a longer piece is required, it is best taken from the tibia. Periosteal covering should be left on the graft. A lateral incision is made in the finger. The graft should restore the normal length of the phalanx (Figs. 137, 138). To relieve the graft of pressure the finger should be put up with extension for four weeks. If either epiphysis is gone, the

raw end of the graft may be covered with fascia and fat and an articular end made.

FIG. 138.—GRAFT FROM TIBIA, COVERED WITH PERIOSTEUM, INSERTED FOR RECONSTRUCTION OF SHAFT OF PHALANX IN FINGER.

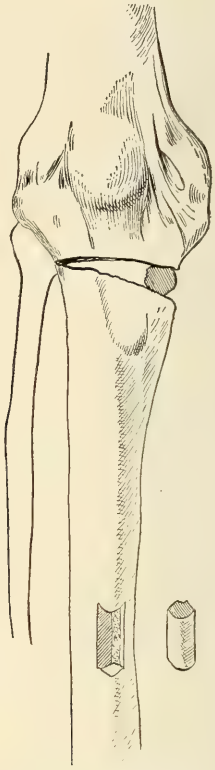

FIG. 139.—METHOD OF CHANGING SHAPE OR DIRECTION OF BONE.

This operation may be used to correct bowlegs or knock-knee. It is the principle employed in osteoplastic operation for club-foot. An osteotomy is done, and a transplant of bone is placed in the fracture gap. (After Albee.)

(From Warbasse's "Surgical Treatment.")

Patella dislocated. In position.

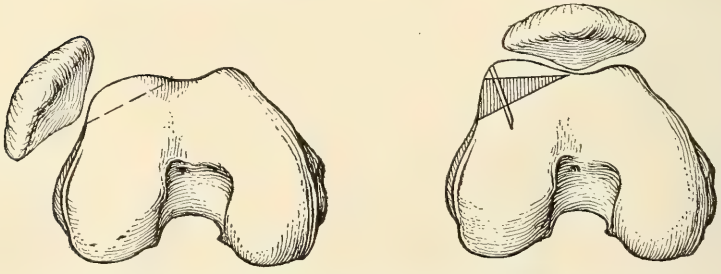

FIG. 140.—OPERATION OF ALBEE FOR HABITUAL DISLOCATION OF PATELLA.

An osteotomy is done and a wedge-shaped graft is pinned in the gap, thus elevating the front of the condyle and preventing dislocation. (From Warbasse's "Surgical Treatment.")

Knee.—Bony Ankylosis with Deformity.—The common flexing deformity seen with bony ankylosis of the knee is best treated by arthro-

plasty to break up the ankylosis and reconstruct the joint. But when an ankylosis in the better position is desired, a wedge may be removed, and with the material of the excised wedge an inlay may be constructed to hold the bones and guarantee secure fixation.

Bow-leg deformity may be remedied by transverse osteotomy of the tibia, and inserting a bone-graft into the chink to make the desired correction (Fig. 138).

Habitual Dislocation of the Patella.—Albee splits up the front of the condyle over which the dislocation occurs, elevates it until a wedge-shaped opening is produced, inserts a wedge of bone cut from the tibia, and holds it with a bone-pin (Fig. 140). This operation should be combined with operation on the soft parts.

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CHAPTER XXXIV

SURGERY OF THE HEAD*

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The best evidence that Cushing's chapter on Surgery of the Head in Volume III of Keen's Surgery, written eleven years ago, is a cornerstone in modern cerebral surgery is that almost everything there put down holds as well at the present time. Such subjects as the general principles of cranial operations, meningeal hemorrhage, fracture, epilepsy, and so on are fully discussed in that chapter, and as yet require no amplification. However, definite progress has been made in a number of directions, particularly in the diagnosis and methods of treatment of hydrocephalus and of brain tumor. These subjects will, therefore, be taken up anew. Craniocerebral wounds in the recent war opened up a new and interesting field for cranial surgery, with many possible applications of some principles there acquired, to the surgery of cranial injuries and of other intracranial conditions in civil life. A consideration of this subject will occupy the main part of this chapter. A number of debatable questions in cranial surgery have arisen in recent years; some of these will be taken up in one or other of the three sections, although all cannot be discussed. Valuable neurologic contributions have been made to the diagnosis of organic cerebral disease, but reference to these will, of necessity, have to be omitted because of limited space. For the same reason a detailed discussion of neurologic manifestations will be omitted, and a working knowledge of organic neurology will be taken for granted.

CRANIOCEREBRAL WAR WOUNDS

Craniocerebral wounds in the recent war have differed greatly from those in previous wars. With the close-range firing of trench warfare and the development of more and more powerful explosive missiles, wounds of the head became not only more common but also more serious injuries. The use of the steel helmet has saved countless lives, has reduced the total number of cranial wounds, and has rendered less mutilating many of those that have been inflicted.† Wounds of the head, nevertheless, remained very frequent and very grave injuries.

Despite the teeming literature on the subject the evolution in the treatment of wounds of the head during the war did not, in a general

* Supplementary to Chapter XXXVI, Vol. III, p. 17.

† An appreciable proportion of the wounds of the head occurred in the temporal and occipital regions below the brim of helmets of the American or British models. Modifications of the brim to protect these regions would certainly have been a valuable added safeguard.

way, parallel that of wounds of the chest, the abdomen, and the extremities. There developed a certain degree of uniformity of opinion concerning methods of procedure for wounds of these regions, whereas the end of the war saw no such general agreement in the treatment of craniocerebral wounds. The widely held impression that the ultimate results of severe wounds of the head were at best unsatisfactory discouraged any wide-spread interest in the subject. Furthermore, there was a general feeling that brain wounds as a class stood apart from wounds of other structures, and hence that their treatment should not be carried out along similar lines. Finally, relatively few of those engaged in military surgery had had sufficient experience in cranial surgery before the war; as a result, head-wounds, as compared with abdominal wounds, for example, did not in general receive either the attention or the skill that their importance warranted. These are some of the reasons for the greater divergence of views on the management of craniocerebral wounds even at the close of the war, and, indeed, for the less perceptible advances that were made in their treatment. To the credit of American surgeons it can be stated that under the leadership of Colonel Harvey Cushing they contributed a real share to whatever progress has been made. This was arrived at not through the development of new or original methods, but by adoption and adaptations of the most desirable elements in the methods of Continental surgeons. In what follows the evolution of various methods of treatment will be reviewed, procedures that appeal from personal experiences as most desirable will be more fully treated, and the immediate and distant results will be discussed, with a double purpose—to standardize as far as possible the treatment of craniocerebral wounds of modern warfare, and to indicate the applicability of some of the lessons acquired from war wounds to the head injuries and non-traumatic lesions of civil life.

Transportation and Place for Treatment.—The ideal *place* for the operative or other treatment of patients with wounds of the head is one somewhat further back from the line than the usual situation of evacuation hospitals (see chapter by Colonel Ashford on the Organization of the Medical Department of the United States Army). This viewpoint is held for the following reasons: Patients with craniocerebral wounds usually stand transportation well, even over long distances and for many hours. This is true regardless of the severity of the wound if the pulse-rate is not greatly accelerated. Urgent indications for operation, such as active bleeding, are rarely present. Apparently infection does not spread as rapidly in head wounds as in wounds of the extremities, for example. Quiet is most desirable in the postoperative treatment of patients with craniocerebral wounds, so that the place should if possible be beyond the zone of loud gun fire. The ideal *hospital* for these cases is one specially planned, equipped, and manned for their care; if that is not obtainable, separate wards for patients with head wounds should certainly be organized. Only in this way can they receive the particular attention they require after operation. Evidence has accumulated to show that patients with head

wounds do not stand transportation well *after* operation, for the proportion of complications appears to have been distinctly higher when patients were transferred to base hospitals shortly (within ten days) after operations for severe wounds. Therefore the ideal hospital plant would be one in which such patients could remain for several weeks or even longer. Unfortunately, very few of these ideal requirements could be attained during the war, especially with the shifting fronts of its later phases. The fact that such arrangements were generally absent in the front area and that patients with head wounds traveled well before operation led (especially in the British lines) to the evacuation of the wounded for their primary operations to base hospitals many miles distant. The unsatisfactory results in the treatment of head wounds under such circumstances was ultimately recognized, for it was found that patients often arrived at base hospitals with wound infections ineradicably established.

Classification of Wounds of the Head.—Many of the classifications that have been advanced were based on prewar ideas, in which the skull and not the injury of the brain had been considered the dominant feature of the wound. It may be going too far to say that the classical teaching concerning lines of fracture in gunshot wounds went for naught, but certainly a detailed knowledge of the bending and bursting radiations of the skull from such a wound was not an essential requirement for the surgeon. Other classifications pivoted on physical signs and symptoms; these were unsatisfactory, for it was found that patients with wounds involving the brain might walk long distances and appear perfectly fit, whereas others in coma with many signs of serious damage might present trivial lesions at operation. There were also too many other factors affecting the general condition, such as battle exhaustion, starvation, or fear, to have made such a classification tenable.

The greatest single element that determined the seriousness of a head wound was the *condition of the dura, whether penetrated or not.* In other words, the decisive factor was *whether or not the chief portal for the development of intracranial infection had been opened.* The best classification is, therefore, one that hinges on this fact. Only by using such a classification can wounds of the head be placed in various categories at operation, since the external appearances of wounds often give such little information about the extent or situation of deeper lesions. Cushing[2] employed the following grouping of head injuries according to their severity, stressing particularly the condition of the dura. His figures for the operative mortality of the various groups are added:

Grade I. Wounds of the scalp with intact cranium and dura. Mortality, 4.5 per cent.

Grade II. Wounds producing local fractures of variable types, with dura intact. Mortality, 9.2 per cent.

Type A. Without depression of external table.

Type B. With depression of external table.

Grade III. Local depressed fractures of various types, with dura punctured. Mortality, 11.8 per cent.

Grade IV. Wounds, usually of gutter type, with detached bone fragments driven into the brain. Mortality, 24 per cent.

Grade V. Wounds of penetrating type with lodgment both of projectile and bone fragments. Mortality, 36.6 per cent.

Grade VI. Wounds with ventricle penetrated or traversed.
A. By bone fragments. Mortality, 42.8 per cent.
B. By projectile. Mortality, 100 per cent.

Grade VII. Wounds of craniocerebral type involving
A. Orbitonasal
B. Auropetrosal region } Mortality, 73.3 per cent.

Grade VIII. Wounds with craniocerebral perforation. Mortality, 80 per cent.

Grade IX. Craniocerebral injuries with massive fracture of skull. Mortality, 50 per cent.

Unless very complicated no classification of head wounds can be free from a certain amount of overlapping. I have employed a simpler classification, which offers perhaps the added advantage of less overlap, in which each group is arranged in the order of increasing severity:*

1. Scalp wounds.
2. Cranial wounds—Dura intact:
   (*a*) Simple fracture.
   (*b*) Depressed fracture.
   (*c*) Bursting fracture.
3. Craniocerebral wounds—Dura torn:
   (*a*) Depressed fracture.
   (*b*) Tangential:
      (1) Ventricle intact.
      (2) Ventricle penetrated by bone fragments.
   (*c*) Penetrating (metal retained):
      (1) Ventricle intact.
      (2) Ventricle penetrated by missile.
   (*d*) Perforating.

There are a number of other factors influencing prognosis that enter into either of these classifications, but their inclusion would only serve to complicate the general outlines above given. A few may be mentioned: The degree and nature of contamination or infection of the wound; existence of other serious wounds; physical condition of the patient; terrain of the battle area.

Symptoms and Physical Signs in the Recently Wounded.—A careful local, general, and neurologic examination should be made in every head wound. The reason for the local and general examination is evident. Since it is undoubtedly true that the neurologic ex-

* What is termed "bursting fracture" corresponds to Grade IX in Cushing's classification. Mention of Cushing's Grade VII is omitted, because cases he has placed in that group appear to me to fall more naturally in one of the other grades, depending on their characteristics.

amination rarely decides the question of operative intervention, its threefold purpose should be stated: 1. To estimate the extent of the cerebral lesion. 2. As a guide for the interpretation of postoperative complications or improvement. 3. For future reference in connection with functional results, late complications, and sequelæ.

Too much emphasis cannot be placed on the fact that the local appearance of the wound is not a guide to the extent of an underlying lesion of the brain or even of the skull. Similarly, the general symptom-complex presented by the patient is not an accurate guide. In a considerable proportion of the cases the physical signs and symptoms are very similar whether the wound be superficial or deeply penetrating. A scalp wound, to all appearances superficial, may mask a deeply penetrating wound of the brain. A patient in coma may have nothing more than a chip fracture of the skull, whereas the next patient, mentally alert, may be suffering from a ventricular penetration. To be sure, a man with a deep gash of the head from which brain substance is extruding is severely wounded. But even such a lesion may not be as serious as one in which there is a slit-like penetrating wound, where damage of the brain, although invisible, may be much more extensive. Positive evidence of brain injury, such as paralysis or hemianopsia, can be evaluated, but negative evidence is worthless either in the diagnosis, the prognosis, or the indications for treatment. Few or many symptoms and physical signs of cerebral injury may be present in patients suffering from craniocerebral wounds. The following symptoms and signs of those that occur therefore should not be understood as manifestations regularly present in the seriously wounded:

Local Signs.—**Hemorrhage** from a wound of the head is rarely observed except on the battlefield. In the great majority of cases there is little or no oozing of blood by the time the patient arrives at a dressing station or evacuation hospital. This is true even when venous sinuses have been torn across by missiles or fragments of bone. Hemorrhage from injury to the middle meningeal artery is very unusual; indeed, contrary to expectation, extra- or intradural blood-clots of large size are rarely found at operation. The only active hemorrhage I saw from a cranial wound admitted to the front area hospital was one from a divided temporal artery. Of course, bleeding from the ears or nose occurs in head wounds with fractures radiating to the base.

The Wound.—Enough has been said concerning the wound itself to indicate clearly the unreliability of drawing any conclusions from it. In many instances the patient enters the hospital with a wound covered by hair matted together by blood-clot and dirt. Only after the head has been shaved will the characteristics of such a wound be apparent. And only then may one or more other wounds of the head that had not been previously suspected be discovered. Finally, at operation the evident wound may turn out to be a simple scalp lesion, whereas the minute, easily overlooked punctured wound may be the entrance of a missile penetrating the brain. Multiple cranial wounds are common or rare, depending on the type of warfare. In the Passchendaele cam-

paign of 1917, when shell fire was employed almost exclusively, I saw multiple wounds very frequently, whereas they were not common with the extensive use of machine guns in the Argonne.

It is futile to make any effort to describe the infinite variations in the appearance of head wounds. Tangential and perforating craniocerebral wounds and "steel helmet" wounds may be selected for special mention. Before the recent war *tangential* (gutter) *wounds* aroused little interest probably because of their less significance with the lower velocity missiles of those days. Tangential wounds were common and caused serious lesions in the recent war. The wound is generally a characteristic one. The furrow or gutter that is cut through the soft parts is of varying lengths and generally wider in proportion to length than in other types of wounds. A striking feature of tangential wounds is that, if severe enough to involve the dura, brain substance almost invariably presents in, and extrudes from, the gap. Another equally

FIG. 141.—DIAGRAM OF THE LESION IN THE SKULL IN A CASE OF DEPRESSED FRACTURE TO ILLUSTRATE HOW THE INNER TABLE (DOTTED LINES) MAY BE FRACTURED TO A FAR GREATER EXTENT THAN THE OUTER TABLE (SOLID LINES).

characteristic feature observed at operation is that bone fragments, frequently of large size, are driven into the brain at right angles to the wound. Short through-and-through (perforating) wounds in which the missile has struck the surface of the skull in transit or has tangentially traversed the skull are included in the group of tangential wounds. *Perforating* (bipolar or through-and-through) *wounds* are the most fatal of craniocerebral wounds, owing to the tremendous brain damage that is inflicted. They also form the group for which the least relief can be obtained by operative measures. The fact that the cranial cavity has been perforated by rifle or machine-gun bullets may be readily overlooked and the wound of exit can easily be mistaken for the *only* wound. This is particularly apt to be the case if the minute entry wound is in an unusual situation, such as the nape of the neck or within the auricle. Perforations opening the frontal, ethmoid, or mastoid cells have been specially grouped by Cushing because meningitis is so likely to super-

vene under such circumstances. The name "*steel-helmet-wounds*" should, I believe, be given to head wounds that are the direct result of wearing this head protector. There are three types that I have noted. In one the helmet has been traversed by the missile and a sharp edge is turned in to be lodged in the skull. The dura may or may not be penetrated. In another the helmet has been driven down on the head, producing a contused or lacerated wound of the scalp, generally in the frontal region. Localized fractures have existed under these lesions in several instances I have seen; in addition, there may be one or more lesions the direct result of missiles. Finally, the skull may be shivered into numerous radiating fractures by the impact of a projectile transmitted by the helmet. A striking feature is that slight if any abrasions or lacerations of the scalp are usually found under such circumstances. Such cases belong to the group of bursting fractures. Many of them cannot, of course, be proved as the result of the force transmitted by

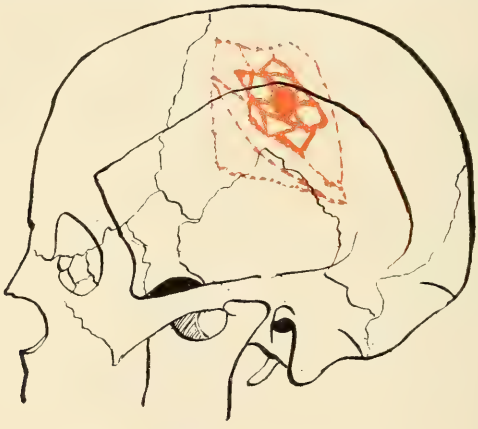

FIG. 142.—DIAGRAM OF THE LESION IN THE SKULL IN A TYPICAL CASE OF PENETRATING WOUND. The solid area represents the site of perforation; the unbroken lines, the extent of fracture in the external table; the dotted lines, the fracture in the inner table.

the helmet. There are a number of authentic instances, however, and I have seen one in which the deeply dented helmet was brought into the hospital by a companion of the wounded man.

***x*=Ray examination** is an absolutely indispensable form of examination of a head wound. Under usual circumstances an operation should never be undertaken without it; in times of stress it has, unfortunately, been necessary to forego the aid derived from roentgenograms. Given, for example, a wound with extruding brain substance, and the difficulties involved in an operation without previous *x*-ray examination are evident. Not knowing whether the wound is penetrating or tangential, one is forced to grope about for a projectile that may not have entered the brain or may have penetrated in a different direction from the one in which it is being sought. The dangers from such unnecessary trauma need not be dilated upon. Exact localization of foreign bodies is not the only assistance *x*-ray examination gives. The existence

of depressed fractures is established. When skull fragments are driven into the brain, their number, size, and depth of penetration are determined; this is of great importance to the surgeon at the time of operation.* In a consecutive series of 45 cases I checked up carefully the interpretations of stereoscopic pictures that had been made; these exactly described the findings at operation in regard to size, position, and number of bone fragments and missiles in 44 of the 45 cases. If *x*-ray pictures cannot be taken, fluoroscopic examinations are of great aid in localizing the situations of fragments of metal, or in determining their absence. During many months' work in a mobile hospital I had to depend entirely on fluoroscopic examinations, and their reliability is, in my opinion, definitely established; but the assistance they give the surgeon falls far short of that derived from *x*-ray plates.

General Symptoms.—Loss of consciousness is common whether the wound is slight or severe. It is of very varying duration, from a few minutes to several days. Stupor or semicoma often alternates with a peculiar restless irritability, making patients exceedingly difficult to manage. Either coma or this irritability is of serious omen if it has lasted a number of hours. In a series of 100 cases admitted to a front line hospital where I was stationed, and in which admissions averaged ten hours after injury, 37 per cent. were admitted in one or the other of these conditions. Only 30 per cent. of those in coma or semicoma, and 60 per cent. of those with restless irritability, recovered. Early in the war a slow pulse was interpreted as indicating cerebral compression. Subsequently, this was found to be incorrect. A slow pulse is often associated with battle fatigue or with inanition, and the pulse is not infrequently rapid with cerebral involvement. In fact, a greatly accelerated pulse is of grave significance; upon examination of my records I find that there was not a single recovery where the pulse-rate on admission was 130 or more, whether operation was performed or not. Headache is the most common complaint of patients entering the hospital; it is generally frontal, regardless of the position of the wound, and bears no relation to the gravity of the wound. Other symptoms, such as vomiting, vertigo, vasomotor disturbances, and so on, occasionally occur.

Neurologic Manifestations.—As stated in the introduction to this chapter, a working knowledge of organic neurology is taken for granted. Detailed descriptions of the many interesting and significant neurologic observations that have been made in patients suffering from head wounds would take too much space and must be sought elsewhere.† In brief, it may be said that evidence of brain injury is afforded by disturbances of motor, sensory, reflex, and visual functions, depending

* The *x*-ray picture cannot be entirely depended upon to establish the presence or absence of slight fractures without much depression, owing to normal irregularities of the shadows.

† Among the important contributions the study by Lister and Holmes[7] on the cortical visual areas may be mentioned. They have shown that special parts of the visual area of the occipital lobes are linked up with special parts of the retina and that there are separate centers for macular or central vision.

upon the region that has been involved. What particularly concerns us in this place is that these disturbances are not necessarily due to destruction of brain tissue by the wound, but may be, and often are, in small or greater part, the result of contusion or edema of the brain about the wound. This explains the surprisingly frequent recovery of function after head wounds, a recovery that cannot, of course, be directly ascribed to operations that have been performed.

From the foregoing it is evident that neurologic examinations are often difficult and not infrequently impossible of execution in some of the wounded. The presence or absence of gross paralyses and changes in the eye-grounds can, however, almost invariably be determined. The most striking neurologic feature of recent head wounds has been, I think, the relative infrequency of paralyses even when wounds were in the regions in which one would expect them. Thus, in the series of 100 cases to which reference has been made, massive hemiplegias with or without aphasia were present in only 7 per cent. and pareses in 9 per cent. An interesting feature, brought out by Dr. L. J. Casamajor in the study of this series of cases, was that the epigastric, abdominal, and cremasteric reflexes were often reduced and sometimes absent on the side opposite to the head wound, even when there were no other evidences of cerebral involvement in the neurologic examination. Cranial injuries having been subsequently found at operation in such cases, the demonstration of reduction or absence of these reflexes, I believe, is of definite value in indicating craniocerebral injury by gunshot wounds. Examination of the eye-grounds is generally of little value. They often show no changes with the severest wounds. Definite choking of the disks is very uncommon. Slighter alterations, consisting in dilatation with occasional tortuosity of the veins and blurring of the disks, are only present (with rare exceptions) in cerebral involvement, and are of value to that extent. Changes in the fundi are most often found in depressed fractures without extrusion of brain substance.

This brief discussion of neurologic signs cannot be left without reference to the so-called "longitudinal sinus syndrome" described by Sargent and Holmes.[8] This striking picture, a rather frequent one accompanying wounds over the midline in the parietal region, consists in a spastic paresis or paralysis of one or both lower extremities, extending to the arms in severe cases. Sargent and Holmes believe the condition to be due to lesions of the longitudinal sinus or of veins entering it. Unquestionably an injury of the vessel frequently coexists, but in the uniform presence of damage to the adjacent paracentral lobes I can see no good reason for attributing the neurologic manifestations to the sinus lesion. I may add that no lesion of the longitudinal sinus or of the vessels entering it was found at autopsy in 2 patients in whom the syndrome had been present.

Indications and Time for Operation.—These aspects of the subject of craniocerebral wounds were the source of much discussion and wide divergence of views during the war. The question of the indica-

tion for and the equally important one of the time for operation are intimately linked. It is patent that the indications for operation when the patient is seen two or three days after injury are totally different from those existing shortly after he has been wounded. Yet this basic difference was not generally recognized until the latter part of the war; the result was a confusion of ideas and, unfortunately, the loss of many lives. The purpose of operation in the recently wounded is the elimination of infective material; the chief indication for operation at base hospitals is the control of infection. In the earlier stages of the war operations at front line hospitals generally consisted in enlargement of the wound, elevation of bone fragments, drainage of brain tracts, etc. Such operations, instead of eliminating infection, established septic wounds and hernia cerebri in many cases. The general impression that resulted was that operations should not be done in the front area, particularly when it was noted that cases arriving not operated on at the base usually ran a more satisfactory course. Only when the correct operation for recent head wounds—one to eliminate contamination—was evolved could opinion logically veer to early operation. Toward the end of the war there was fairly general agreement that the time for operation on craniocerebral wounds was the time for operation on other wounds, and that the main indication for operation on head wounds was the same as in other wounds.

FIG. 143.—DIAGRAM OF A TYPICAL TANGENTIAL WOUND.

The solid area represents the defect in both tables of the skull, and the unbroken lines, fracture in the outer table. Fragments of the inner table, represented by dotted lines, are detached and driven into the brain at right angles to the wound.

The indications for operation, then, are clear in wounds definitely involving the brain. From what has been said of the ever-open question of deeper involvement in apparently superficial wounds, the indication for operations under such circumstances is exploration. Even though a patient walks without difficulty, does not suffer from any symptoms, has no neurologic signs of injury, is, in short, fit in every way, his scalp wound should be explored as the only means of determining if there is any deeper damage. Cerebral compression from blood-clot is, as has been said, so unusual an occurrence that it need only be mentioned in passing as a rare indication for operation. It has already been noted that neurologic manifestations may be due to destruction of brain substance or edema and contusion, or to both, and it is impossible to differentiate between these conditions. Therefore neurologic symptoms and signs are not in themselves indications for operation. No matter how severe the cerebral lesion, the patient should be given the chance of operation if there is any likelihood of his withstanding it. The surgeon is not the judge of whether a life is going to be worth while living, so long as there is a chance of the life being spared.

Besides, like others, I have had the agreeable surprise of witnessing not only recovery but also recovery with good function in apparently hopeless cases.

As already stated, the indications for operation on head wounds at base hospitals are totally different; they will be discussed after taking up the operative technic for, and complications following, recent wounds.

Contraindications to Immediate Operation.—An operation for a head wound should not be done at a front area hospital unless it can be adequately performed. This involves a satisfactory armamentarium, arrangements for good asepsis, and the reasonable assurance that patients with severe wounds can remain for at least a week after operation. Operation is contraindicated in manifestly hopeless and moribund cases. It is not indicated, or should at most consist in local toilet of the wounds, in the great majority of perforating craniocerebral lesions. In bursting fractures with insignificant wounds operation is usually not required; if necessary, it consists in a subtemporal decompression. The complete operation to be described is contraindicated in large multiple scalp wounds without evidences of depressed fracture because of the difficulties in closing the scalp under such circumstances. Finally, operation is inadvisable, in the absence of symptoms, in penetrations by very small fragments of metal when the wound of entry is not soiled.

The Operation for Recent Craniocerebral Wounds.—The evolution of the operation for wounds of the head has already been indicated. Wounds were at first freely incised, bone fragments elevated or removed, and brain tracts drained. After the unsatisfactory results of such procedures became recognized the general plan was to defer the treatment of cranial wounds until arrival at base hospitals. Here, various methods of flap operations with drainage of brain tracts were evolved; the results were, on the whole, unsatisfactory, but better than the incomplete operations done at the front. A later development, as a consequence of frequent failures by the foregoing methods, was the attempt, both in front line hospitals and at the base, to secure primary union after excision of the wound. But the principles of *débridement* (see Dr. J. H. Gibbons and E. H. Pool's chapters) were not yet established, excision of the wound was accordingly incomplete, and the results were still far from acceptable. The pioneer work of French surgeons (particularly Lemaître[6]) and of Depage and his co-workers in Belgium definitely settled the methods for débridement of wounds in order to insure primary union after suture. There remained the necessity for the application of those principles to cranial wounds. A special adaptation was, of course, necessary, for brain tracts could not be laid open and excised. In fact, the term "débridement" strictly applied to a craniocerebral wound is a misnomer, because brain tracts cannot be so treated. Happily, the deeper portions of craniocerebral wounds generally appear to be less contaminated by bacteria and foreign matter than wounds of other regions because of the combined obstacle offered by the scalp and skull. It was the modified treatment of brain tracts

along the lines of débridement, together with the true débridement of the portion of the wound involving soft parts and bone, that led to the best results obtained in operations for craniocerebral wounds.

These are, in a general way, the stages through which operations for head wounds passed. However, there were individual surgeons, mainly French, who practised fairly complete operations with primary closure long before the method was widely accepted. The work of De Martel[3] should be particularly mentioned in this connection, for he persisted along these lines almost from the outset of the war.

Before describing the steps of the operation it may be well to mention the fact that the wound of the head is often only one of many wounds. In an analysis of the first series of 100 cases I treated, the great majority of the patients had wounds other than cranial. These wounds were serious in 11 per cent. of the cases; there were, in addition, 4 cases in which they were the cause of death. The point is that such other wounds cannot be slighted because of concentration on the head lesion at operation; I know that there were at least 2 cases in my experience in which death ensued from infection in these wounds, most likely the result of the inadequate operations that were performed. The average duration of an operation for a craniocerebral wound is somewhere between an hour and a half and two hours. Therefore another surgeon with his assistants should operate simultaneously on the other wounds if the latter require prolonged procedures. Furthermore, it sometimes becomes a matter of careful judgment whether or not to defer operation on the head wound in the presence of another serious wound more urgently requiring an extensive operation.

Preparation of the Scalp.—The entire scalp should be shaved for a number of reasons. It is impossible to say in advance how extensive an exposure will be needed. Other wounds may be disclosed. Various wide-sweeping plastic incisions may be required for scalp closure. Cushing[1] objects to preparation of the skin with iodin because it is apt to be followed by crusting and scaling, but I believe that that objection is outweighed by the advantages inherent in the penetration of the dried scalp by iodin. He also advocates the application at the field ambulance of a warm soap poultice to the wound, a procedure that is inadvisable, I think, because it would be apt to be a chilling dressing by the time the patient arrived at the hospital. In some French units the scalp was close cropped before the men went into action. This admirable precaution may very well have lessened the infectivity of not a few cranial wounds and certainly rendered less difficult the trying task of shaving the scalp.

Anesthesia.—The use of local anesthesia in operations for head wounds was developed chiefly by French surgeons, De Martel in particular. He clearly pointed out some of its many advantages. These will be discussed in connection with operations for brain tumor, but should be especially noted in this place. The objections to general anesthesia are: increased intracranial tension encountered at operation, with a resulting tendency to herniation of the exposed brain

and forcible expulsion of the contents of a brain tract; increased bleeding from the scalp and bone, as well as from cerebral vessels; the tendency to the development of respiratory complications after operation; the necessity for careful observation of the patient until recovery from the anesthetic, and, of course, the necessity for a skilled anesthetist, not always to be had. The advantages of general anesthesia are: reduction in time consumed in preparation for operation, and the elimination of the difficulties in shaving restless patients. But these are counterbalanced by the many desirable features of local anesthesia. Besides overcoming the objections to inhalation narcosis that have been enumerated, local anesthesia is apt to encourage gentler and more accurate methods; the patient can be operated upon in a semi-sitting posture (De Martel); he can often co-operate by changing the position of his head when desired, coughing or straining to help express the contents of the brain tract, and so on. Local anesthesia cannot be satisfactorily employed in some of the patients suffering from the peculiar restless irritability that has been described. Unfortunately, shaving and anesthetization of the scalp are time consuming, and when many cases have to be operated upon and there is not at hand the assistance required for the preparation of succeeding cases while the surgeon and his team are operating, resort must be had to general anesthesia.

It is generally advisable to administer some narcotic before operations under local anesthesia. Omnopon was extensively employed by British, and scopolamin by French surgeons. One per cent. novocain with adrenalin (added in the proportion of 1 c.c. to 30 c.c. novocain) is injected about the area of the wound and along the lines of the proposed incision. If sufficient time is given for this to take effect, additional infiltration with the anesthetic is usually unnecessary during operation.

Excision of Scalp and Bone.—This part of the operation, as practised by De Martel and other French as well as British surgeons, consisted in turning down a large osteoplastic flap with the wound in its center, and subsequently excising the wound tract. The objections which I believe to be inherent in flap methods are: unnecessary difficulties in technic; the need for huge flaps with the larger wounds; the manifest undesirability or impossibility of flaps in certain regions; difficulties in the treatment of postoperative infections, especially hernia cerebri, should they arise; and difficulties in scalp closure after excision. The principle of simple excision of scalp and bone was, therefore, evolved, dependence being placed upon one of a number of methods of plastic incisions if required for closure of the scalp. The method employed by Cushing was an incision about the wound with three radiating ("tripod" or "Isle of Man") incisions extending from this. By reflecting these flaps adequate exposure of the skull was obtained. In the ordinary type of wound I generally employed a simple long, elliptic incision circumscribing the wound, placed to give the necessary exposure in the desired direction. The ends of this incision were curved one

way or another to permit the scalp to be reflected where greatest exposure of the skull was required. The incision employed by Cushing was designed, of course, not only for exposure, but for subsequent plastic closure. I believed that the necessarily extensive reflection and undermining of flaps was undesirable if postoperative infection should supervene, and that the junction of three flaps at one point overlying exposed brain invited infection of the brain and the development of hernia cerebri, should there be any infection in and separation of the scalp wound. As will be subsequently indicated, plastic incisions were not infrequently required for closure after the elliptic incision, but I believed that the time for their consideration (as in breast amputations for carcinoma, for example) was at the end of operation. After all, the important point is that, in accordance with the principle of débridement, the wound should be completely circumscribed, not omitting the minutest visibly devitalized or soiled portion of scalp. In the beginning unnecessarily wide areas of scalp were sacrificed, until it was learned

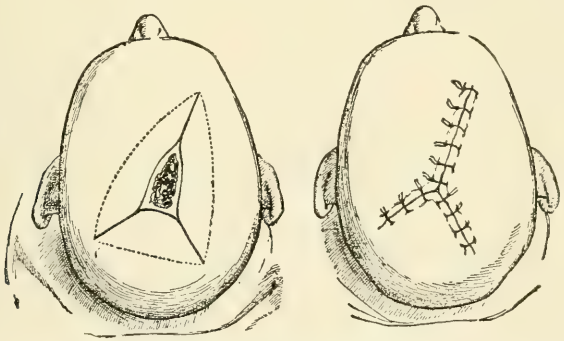

FIG. 144.—THE TRIPOD INCISION FOR SMALL IRREGULAR WOUND OF VAULT.
Dotted lines indicate area of reflection of flaps. Drawing to the right shows method of closure. (Cushing, in "British Medical Journal.")

that the incision could safely be placed a few millimeters from the margin of the wound. The incision is deepened to bone, all devitalized areas in the soft parts being circumscribed.

The excision of the depressed fracture, as advocated by Cushing, consists in making a number of small perforations in the skull immediately beyond the bony lesion, and connecting them with linear cuts through the bone. Forceps of the De Vilbiss pattern may be used for the latter, but the Montenovesi forceps is best adapted for the purpose. It makes an excellent linear cut, can be introduced through smaller openings, turns corners more easily, and is less jarring. After the perforations have been joined up, the section of bone is uptilted and scalp and bone are thus removed in one piece. The advantages of this technic are evident. The soiled area is removed in one piece, there is immediate exposure of the underlying lesion, and the mosaic of bone fragments can be examined to see if it is complete. The first point requires no elaboration. The complete exposure that is immediately obtained is particularly advantageous in sinus lacerations, for other-

wise removal of a fragment of bone lodged in such a sinus before the field has been adequately bared generally leads to hemorrhage that is difficult to control. By possessing the mosaic of bone fragments one can determine if any parts are missing, and accordingly seek them.

This type of block excision was, therefore, strongly urged by Cushing. Although admirable for many varieties of wounds, I found some objections to its routine application. In the first place, it cannot be readily employed in wounds toward the base of the skull, such as those involving the mastoid. In cases in which damage to the skull is merely suspected, or when a superficial bone lesion is anticipated, I believe areas of skull are unnecessarily sacrificed thereby.* In such instances I think it better to excise the scalp wound with periosteum and then examine the bone. When extensive depressed fracture exists, block removal of bone can be carried out. If there is a superficial chip fracture, a perforation can be made to one side, and the involved portion of the skull is then lifted out with a rongeur forceps. The latter is discarded and fresh rongeurs used should the opening require enlargement for the removal of depressed fragments of inner table or for the treatment of a

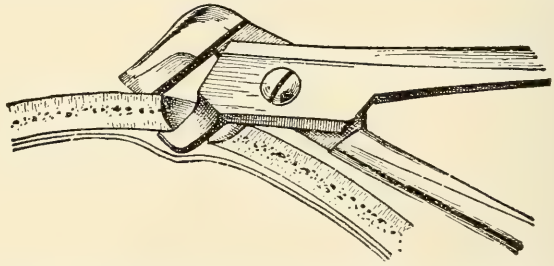

Fig. 145.—Montenovesi Linear Cutting Forceps to Follow Burr. Drawing about ⅓ natural size. (Cushing, in "British Medical Journal.")

dural tear. Another objection to block removal of skull is that, in that method, the lesion of the outer table is the guide to the amount of bone to be removed. As is well known, fracture of the inner table is often more extensive and the depressed fragments cover a broader area than would be indicated from the fracture of the outer table. In such instances the block removed may well include only parts of the inner table; I recall two instances in which I inflicted unnecessary trauma by depressing fragments of the inner table with the jaw of the bone-cutting forceps under these circumstances. Furthermore, a superficial tear of the dura may be converted into a deeper one upon tilting the block should a pointed fragment of bone be firmly locked in the dura. These objections are not to be understood as outweighing the advantages of block removal, but as indicating what I believe to be its limitations.

A different technic which I have used in many cases may be described as follows: After excision of the scalp with its periosteum, a perforation

* The removal of any more of the skull than is required for the débridement or adequate exposure is no small matter; as will be shown, the question of repair of defects often arises at a later date.

is made to one side of the bone lesion. With rongeurs and linear cutting forceps the bone is cut away progressively along the margin of the fracture. If more extensive inner table depression is found, the bone is removed widely enough to expose this completely. After the rim of bone about the fracture has been excised, a blunt elevator is used to separate the depressed fragments from the dura. The mosaic is removed in one piece when it appears safe to do so. However, when the lesion is in proximity to a venous sinus, when fragments are firmly attached to the dura, or when a dural tear is suspected, the fragments are lifted out in small sections. In suspected sinus injury removal of fragments is begun away from the sinus region, so that the exposure is adequate and preparations complete to treat a sinus tear upon removing the last fragments. The instruments used for the removal of the mosaic are soiled and therefore discarded. With large defects in the skull, as in tangential wounds, this technic is also very satisfactory for débridement of the bone. Although not as neat as block removal, I consider the method safer under the circumstances that have been indicated; it is always simple of application and attains the same ends as removal *en bloc*.

Whatever technic of débridement is employed, the resultant exposure should be sufficient for the treatment of the underlying lesion. With large dural tears enough bone must be removed completely to expose normal dura all around, except in those regions (tears going down toward the base) in which this is not feasible. Linear fractures radiating from the cranial penetration are not followed except when bone removal along them is required for the exposure of a lesion underneath.

Treatment of the Intact and the Torn Dura.—Any blood-clot adherent to the dura may be contaminated and is therefore gently cureted away. The question of incising an intact dura not infrequently arises when its surface is discolored, tense, and not pulsating, especially if paralysis or other functional loss exists. It is always a most difficult question to settle in the presence of a soiled wound. Some hold that an intact dura should never be incised; others, that it should be invariably opened if indicated for the removal of blood-clot or disorganized brain. Surely the dura should not be incised under any circumstances unless one is certain of the operating-room asepsis, of the débridement of the wound, and of the uncontaminated condition of the part of the dura it is proposed to open. The possible or even probable advantages of incising the dura must always be weighed against the ever-present possibility of a fatal infection that may result. It is impossible to draw any definite conclusions in favor of or against incision of an intact dura from the literature on the subject because most writers fail to give facts to support their assertions. In my own experience the dura was not opened in any of the cases in which it was intact, although in a number there were definite evidences of underlying damage. *There were no deaths.* Recovery from paralysis or other loss of function was perhaps slower than it might have been with incision of the dura, but the follow-up notes show a satisfactory outcome in all the cases.

A dural tear is generally large enough for the exploration and treatment of an underlying brain tract; if not, it must be opened to the required extent. Most surgeons contend that the margins of the torn dura should be left undisturbed, the argument being that otherwise adhesions are separated and an infection of the meninges invited. I hold that an adequate débridement includes removal of the devitalized margin of the dura (1 or 2 millimeters) as a necessary step, and I have seen no meningeal complications referable to such excision. When the head wound is definitely infected the stage for true débridement is, of course, past, and the sealed-off meninges must be respected. But in the earlier period every effort is bent toward obtaining primary union, and excision of the dural margin is part of the procedure. It is usually attended by fresh bleeding readily controlled by ligating one or two vessels with fine silk. Débridement of the dural margin is best done after the toilet of the brain tract.

Treatment of the Brain Tract.—This is the most important single step in the operation in wounds with cerebral penetration, for the removal of the cerebral débris, blood-clot, bone fragments, and bits of cloth plugging the tract means the elimination of the greatest factor favoring brain infection. Fortunately, a considerable portion of the contents of the tract will frequently extrude spontaneously (or after removal of superficial fragments corking the tract) if the patient can be made to cough or strain, or with the increased tension that usually exists in general anesthesia. The method generally used for removing deeper bone fragments, until Cushing introduced catheter suction, consisted in the insertion of a finger to dislodge bone fragments, alternating this with irrigation of the tract. These procedures were repeated until the tract was free from bone fragments and débris. Unquestionably digital exploration may inflict damage to the walls of a brain tract, even when done with the greatest gentleness. Therefore Cushing's technic is a real contribution, since the tract is well and safely cleaned thereby and the use of the finger is eliminated. It is employed as follows: "Reliance was placed on the use of a flexible, soft-rubber catheter as a means of determining the exact direction taken by the missiles, whether a metallic body or bone fragments, or both. Without the production of additional trauma one may investigate in this way even the narrowest track, and it will be found that the presence and situation of any in-driven bone fragments can be detected with almost as great delicacy as by direct palpation. By attaching to the end of the catheter a Carrel-Gentile glass syringe with its rubber bulb it is possible to suck up into its lumen the softened brain, which can then be expelled from the catheter as paste is expressed from the orifice of a tube. The process should be repeated until the cavity is rendered as free as possible of all the softened and infiltrated brain. It will be found that the adjoining normal cerebral tissue, unaffected by the original contusion, will not be drawn into the tube by the degree of suction which can be applied by the average rubber bulb. Not infrequently bits of bone come away in the eye of the catheter, and on one or two occasions a small foreign

body has thus been withdrawn. Meanwhile, as the track becomes clean and the tension and tendency of the brain to herniate subsides, it is possible with delicate duck-billed forceps to pick out from the track one by one the bone fragments, whose depth and position can be determined by the unmistakable sensation they impart to the catheter, which thus supplements the information given by the *x*-ray plates. The technic of the performance will quickly be acquired by any one who may wish to put it into practice."

Before this technic was described I had always explored digitally those brain tracts wide enough to admit the finger freely, reserving the instrumental extraction of bone spicules, débris, or foreign bodies for the narrower tracts. Entirely converted to the routine use of catheter suction, I see no objection and one real advantage in additional palpation of such large tracts, *provided it is done carefully.* My usual pro-

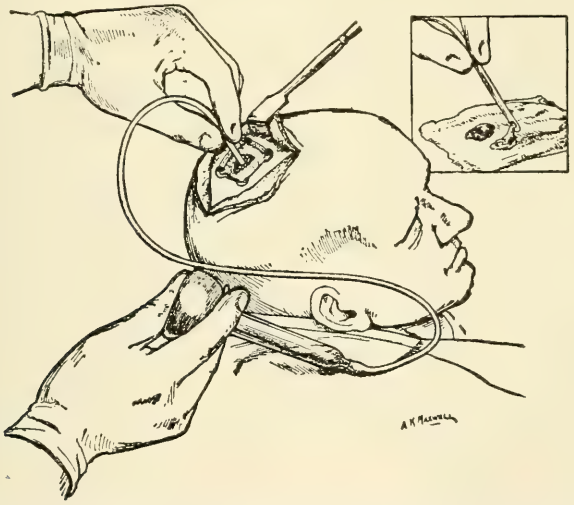

FIG. 146.—SKETCH TO ILLUSTRATE THE METHOD OF SUCTION OF THE TRACK OF A PENETRATING WOUND. (Cushing, in "British Medical Journal.")

cedure in these wider tracts has been painstakingly to cleanse the track with alternate flushing and suction through the catheter, using delicate forceps to remove bone fragments felt with the tip of the catheter. When the tract has been rendered as clear as possible a finger is introduced and the walls are palpated for any embedded bone fragments that may have been missed. Upon a number of occasions I have found and dislodged such fragments in this way. In fact, bone fragments buried in the wall of the tract can be felt with the catheter only by the merest chance. When felt, it has been safer in my hands to dislodge them with the finger rather than to use an instrument that may readily traumatize surrounding brain tissue.

Although single brain tracts are the rule, it should not be forgotten that two or more fragments of metal may enter through one skull open-

ing (or the missile may be split up in transit through the skull) and penetrate the brain in different directions. The *x*-ray would, of course, indicate the existence of multiple foreign bodies in the brain, but it is not apt to establish penetration through a single skull opening. I recall an instance of double penetration with the parallel tracts not far apart, and again, a single penetration with three forking tracts in a case with multiple scalp wounds. One must, therefore, be on the watch for multiple tracts in order to avoid missing minor ones; larger penetrations could scarcely be overlooked. Minor tracts require the same detailed attention as the wider, more evident penetrations.

There is no essential difference in the treatment of the tract in the more serious cases of *ventricular penetration.* Until catheter suction was employed the existence of this condition was usually only surmised at operation from the path of the missile or was found after death. With catheter suction the diagnosis is promptly made by drawing cerebrospinal fluid up into the syringe. Bone fragments should be extracted from the tract even more carefully than ordinarily for fear of dislodging them into the ventricle. The ventricle can be sucked dry. In wide tracts two long, thin-bladed retractors may then be introduced and inspection made of the interior of the ventricle with reflected light to discover bone fragments or a missile in the cavity. There appears to be a definite tendency (because of the resistance of the fluid) for foreign bodies that have penetrated the ventricle to be retained there rather than to become embedded in brain substance beyond. Their retention in the ventricle is almost sure to be fatal, and therefore every justifiable effort should be made toward extracting them. Fortunately, not a few ventricular penetrations are the result of puncture by one or two long slivers of bone that can be easily removed.

Before catheter suction was introduced ventricular penetration was thought to be a hopeless lesion. We now know that the mortality from penetration by bone fragments is not much higher than when the ventricle is intact. The rôle of dural repair in the results that may be obtained will be subsequently noted. Cases in which the missile penetrates the ventricle appear to be quite hopeless; however, I have had one certified case that recovered after operation.

Treatment of Devitalized Brain Tissue.—This aspect of the treatment of the cerebral wound is not usually discussed by writers; yet it is a definite step in the technic. Manifestly the devitalized portions of brain around the cerebral tear should be subjected to débridement as a necessary element in the effort to avoid infection. They are sure to slough and are already contaminated. Snipping off dangling fragments does not suffice. Devitalized fragments should be removed freely enough to obtain some oozing from the surface that is left. It is clear that serious functional loss may occur if one cuts widely into healthy brain substance. By closely hugging the devitalized fragments with a sharp scalpel or fine pointed scissors no harm will be done. Partially detached tags of pia-arachnoid are generally found where there is much cerebral laceration, and they, too, should be ablated.

Extraction of the Missile.—Subsequently it will be shown that the retention of a missile in the brain is not the essential element in the development of late complications after craniocerebral wounds. Yet the extraction of the foreign body is eminently desirable not only for the elimination of an important element favoring sepsis but also because infective material about the missile and in the tract leading to it is thereby removed. The ideal time for extraction of the foreign body is at the primary operation, for there then exists a track acting as a guide to its situation. In extractions at a later date cicatricial tissues (or normal brain) must often be traversed, and there is greater likelihood of injuring adjacent brain substance. "Latent sepsis" has been lit up, according to some reports, in late foreign body extraction. Therefore every reasonable effort should be made to extract the foreign body at the primary operation. When superficially situated in the brain, this is a simple matter. There has been considerable difference of opinion concerning the advisability of the removal of deeply implanted missiles, some urging that they should be left alone. I believe a middle ground between these extreme views is the justifiable position to hold, namely, that every reasonable attempt should be made to extract the missile, always provided that serious damage to the brain be not inflicted by the maneuvers.

Small fragments of metal are not infrequently drawn into the eye of the catheter in the suction method, and removed in this way. After the tract has been freed of débris a foreign body sometimes becomes freely exposed at the apex and can be readily removed. Magnet extraction is usually required for deeply seated missiles. The safest method consists in gently introducing a slender rod (made specially for that purpose) to the bottom of the tract (the length and direction of the tract are determined by the catheter and the position of the foreign body by the *x*-ray) and then making contact with the portable electromagnet. The foreign body is withdrawn along the track. Needless to say, fragments of magnetizable metal are the only ones that will respond. The use of too powerful a magnet, one that will make a piece of metal jump some distance, is most inadvisable. Deeply placed foreign bodies can frequently be extracted either with forceps or with the magnet. In my series they were removed in a little over half the cases. I had one unfortunate experience with magnet extraction. It was an instance of ventricular penetration by a large missile. The fragment was half-way out of the tract when (because of its weight, or possibly because of poor contact) it dropped back. It was found in the ventricle only after considerable difficulty, and finally removed with forceps. The patient died about twelve hours after operation. French surgeons have employed extraction by means of the Hirtz localizing compass to which the extractor is attached. They also practised extraction under guidance of the fluoroscopic screen. Both methods have given satisfactory results, but, unless practised with extreme care (which means that the extractor must remain in the tract), injury to the brain will be inflicted.

Control of Hemorrhage.—Hemorrhage at operation can usually be controlled without any great difficulty except when it arises from a distant region such as the base of the skull; this, however, is an unusual occurrence. In order to prevent a postoperative collection of blood that readily can become infected, it is essential that the field shall be dry at the end of the operation. The simplest way to avoid this is to establish hemostasis step by step. Bleeding from the bone is usually trivial and ceases spontaneously. The application of Horsley's bone-wax ordinarily controls any excessive bleeding, but for large vessels in the bone wooden plugs or small pieces of muscle used as plugs may be required. Laceration of the middle meningeal artery is infrequent. Bleeding from small branches at the torn dural margin is frequently encountered. In either instance hemostasis is established with silk ligatures or by using Cushing's silver clips.

Hemorrhage from torn venous sinuses does not offer great difficulties if the lesion is adequately exposed. The application of a fragment of

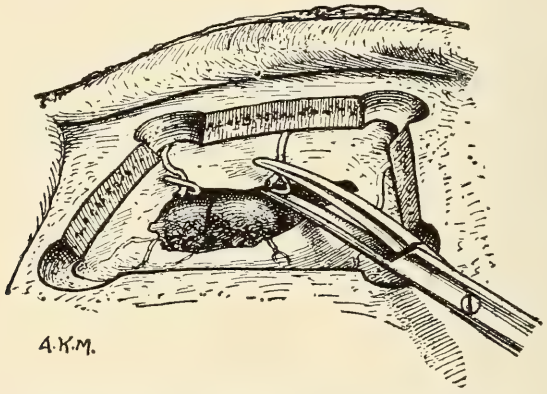

Fig. 147.—Showing the Method of Placing Silver Clips on the Vessels of the Dural or Meningeal Margins. (Cushing, in "British Medical Journal.")

muscle (or of aponeurosis if muscle is not accessible) is remarkably efficacious. The "postage-stamp" graft is held gently in place with the gloved finger for a minute or two, at the end of which time bleeding will have ceased. Large sinus tears may require suture with fine silk, or silver clips may be employed. On several occasions I have seen the longitudinal or lateral sinuses torn completely or almost completely across. In such instances I practised ligation of the divided ends. Muscle grafts might have established hemostasis, but I felt that secondary hemorrhage might supervene if infection of the blood-clot occurred. Ligatures could not be securely thrown around the ends of the vessels, and I therefore employed the following technic: A short distance beyong the tear small nicks are made in the dura on either side of, and directly adjacent to, the sinus wall. The flat, blunt-pointed end of a probe with the eye carrying a silk ligature is bent to the desired shape (like a small aneurysm needle) and gently passed beneath the vessel. Slight pressure on the needle when the membranous fold beneath the

vessel is reached suffices to penetrate it. The triangular shape of the sinus in cross-section must be borne in mind, otherwise the vessel wall may be injured. The ligature should be tied only snugly enough to obliterate the lumen.

Bleeding from the lacerated brain requires little discussion. Ordinarily, it is well controlled by the application of moist or dry pledgets of cotton. Sometimes there is persistent oozing from one or two places, and bits of muscle should then be employed for hemostasis. Bleeding cerebral vessels are ligated with fine silk. Torn cerebral vessels, thrombosed and not bleeding, are occasionally met at operation; if the divided ends are free, the vessels are tied and the excess portions ablated.

Repair of Torn Dura.—Suture. Transplantation of Fascia.—This aspect of the craniocerebral wound has received scant attention. Surgeons were apparently satisfied with the removal of soiled and infective material and did not devote much consideration to the question of repair. Some sutured the smaller dural lacerations that could be closed, others left them open as a sort of safety-valve in the event of suppuration in the brain tract. The argument against closure of the dura was, of course, the danger of locking in an infection. But the whole plan of treatment as described is based upon the elimination of infective material, and its success is entirely centered thereon. Undoubtedly, suture of the dura would reduce the chances for recovery in some cases by closing off infective foci in brain tracts; however, the prognosis, whether immediate or ultimate, is always bad if such foci are left behind. A detailed consideration of the advantages of dural closure is included in the discussion on fascial transplantation. I believed that dural closure was a required step in the operation, and I therefore employed it as a routine procedure, omitting this step only in a small proportion of the cases under my care. These were wounds in the right temporal regions in which subtemporal decompression was done; wounds with purulent brain tracts; wounds in which the tear in the dura could not be adequately exposed; and finally, wounds in patients in too poor condition to devote the additional time for dural repair. Before dural suture is begun the devitalized margin is excised in the technic I have employed, as previously noted (p. 152). By passing the interrupted sutures first at one and then at the other end of the tear, and thus working toward the middle, some lacerations apparently too large for suture can be closed.

In many cases, however, the loss of dural substance is too great for closure. For these, I employed fascial transplantation. Without entering into details, I may say that fascia lata has been experimentally and clinically proved, by myself and others, to be an eminently satisfactory tissue for the replacement of visceral defects. Implanted into a dural gap, it becomes gradually replaced by a firm fibrous connective tissue almost indistinguishable from the dura, and lined by a layer of cells continuous with the dural endothelium. The reasons for suture of the smaller and fascial transplantations for the larger dural defects may now be enumerated: 1. To obviate

infection from without, especially when bone sinuses have been laid open by the injury. 2. To minimize the chances for subdural infection in the event of postoperative infection or separation of the scalp. 3. To prevent leakage of cerebrospinal fluid in wounds with ventricular penetration. 4. To prevent adhesions between the lacerated brain and the scalp. 5. To afford a permanently firm physical protection for the brain surface. 6. To eliminate the possibility of injury to the brain at a subsequent reparative operation.

Before transplanting fascia the devitalized margin of the dura is excised. The technic of fascial transplantation, detailed in another place (page 183), is simple. As applied to craniocerebral wounds it consists in removing a portion of the fascia lata of the appropriate shape of and slightly larger than the dural gap, and fixing the transplant in place by four silk sutures. Interrupted stitches are placed between these, approximating edge of fascia to edge of dura. The transplants varied in size from 2 x 2 to 4 x 4 cm.

It is evident from the foregoing that fascial transplantation was employed only in serious cases, those in which there was much damage to the brain in keeping with the large dural tear. Of the 19 cases in which I used fascial transplants, 7 died. One of the deaths occurred four months later as the result of sepsis from a compound fracture of the leg. The autopsy showed the transplant well healed in place. The condition of the transplant is known in 4 of the surviving 12 cases, for they were subjected to reparative operations. The transplant was described as satisfactory in all; in fact, in two instances operators were not aware that fascial transplantation had been done. Altogether, follow-up reports have been obtained in 9 cases, and in none were there symptoms that could be referable to the transplant acting as a foreign body. The first operation was done more than two years ago, and the last, a year ago. Sufficient time has thus elapsed to be able to state definitely that the ultimate as well as the immediate results of fascial transplantation in cerebral wounds are eminently satisfactory.

Indications for Drainage.—The sutured scalp incision is drained in one or several places if the head wound has been definitely infected. If a brain tract is found to be purulent, or contains manifestly infected blood-clot, its drainage is indicated. Hemorrhage should be a rare indication for drainage. Altogether, drainage should be considered a very unusual feature after a properly conducted operation for a recent wound, for it defeats the purpose of the operation.

Closure of the scalp should and can be complete in the great majority of cases. The exceptional instances are infected wounds or multiple wounds with extensive loss of scalp. In suturing the scalp a separate layer of sutures is devoted to the aponeurosis. Better approximation is thereby obtained, additional support is given, hemostasis is established, and the external sutures can be removed at an earlier time. With the tripod incisions that have been described closure was generally obtainable by sufficiently extensive mobilization of the flaps. Simple suture of the wound could be carried out in a large proportion

(80 per cent.) of the cases in which the long elliptic incision I have described was used. In the remainder some type of plastic closure was required. The one I used most frequently was the S-shaped variety. The scalp is sutured from both ends as far as possible. Then, beginning at one end of the remaining defect, an incision is made through scalp and aponeurosis at right angles to the axis of the defect. This incision is carried down a varying distance, depending on the required size of the flap, is then curved to run parallel to and for the full length of the defect, and is again turned down to run parallel to the first part of the incision. The resultant flap is now completely freed, slid over the defect, and sutured in place. The plastic incision can be closed completely in most instances by passing the sutures obliquely; a remaining defect at the furthermost part of the incision, however, is of no moment. The success of the S-shaped plastic depends on its accurate placement, and, above all, on its length. The tendency is to make it too small, with an inadequate flap as a consequence. In a large defect over the forehead, for example, I have fashioned the plastic S-shaped incision so that its end reached beyond the occipital protuberance. Some of the defects of the scalp are of triangular or shield shape. Plastic closure of these consisted in prolonging the base of the defect on both sides to lengths sufficient to mobilize the two lateral flaps required for closure. There remained a small proportion of cases in which no typical plastic incision could be employed, and in these various incisions had to be devised to fit the particular case.

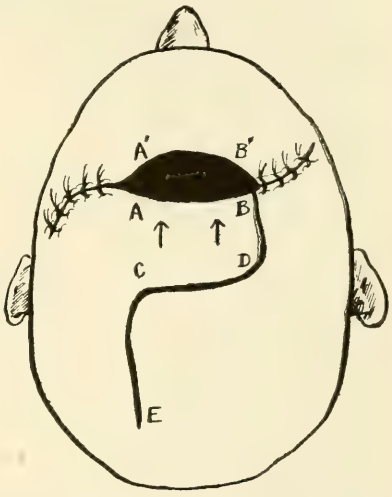

FIG. 148.—TECHNIC OF THE S-SHAPED PLASTIC.
The flap, A–B–C–D, is completely detached from the pericranium. As a result of the prolongation of the incision to E the flap is freely movable and A can be readily approximated to A′, B to B′.

Had the war continued the entire question of closure of the scalp might have been put on a very different basis. Following débridement wounds in other parts of the body were either sutured primarily or subjected to delayed primary suture, depending on certain factors, such as the presence of streptococci in the wound. Similarly, delayed primary suture of the scalp in craniocerebral wounds might very well have been developed as a desirable refinement of technic.

Postoperative Course and Treatment.—In the lightly wounded the postoperative course is usually smooth; however, severe headache and dizziness are not unusual. In craniocerebral injuries, on the other hand, the course is often stormy even in those patients who are doing well. Rise of temperature may occur without any evidence of local or general infection. Restlessness is common, and, particularly at night,

patients may become very violent, attempting to tear off dressings, get out of bed, and so on. This peculiar "dream state" may last a week or even longer, and yet be followed by complete recovery. It is not in itself of serious omen. Very frequently there is a complete amnesia for the events of the first two weeks after operation even in the lightly wounded. Indeed, many patients have written me that they remembered nothing or almost nothing of occurrences for a month or more after injury. And yet, not a few of these men seemed normal in every way at the time of leaving the hospital one to two weeks after operation. The treatment of some of these patients in the first days after operation, particularly as regards the mental state, the matter of feeding, and so on, is often very trying. The question of nursing is a most important element in the results that are obtained. Loud noises and clumsy handling have very disturbing effects on these patients. The administration of morphin not infrequently results in increased restlessness and violence. Chief reliance should be placed upon the bromids, used as a routine by some. Aspirin and trional given together are often efficacious for headache. Rectal administration of bromids and of fluids, in patients who cannot or should not take anything by mouth, is very beneficial.

It is usually not difficult to recognize within a day or two the cases that are not doing well. Coma persists, or those who have been alert complain of bursting headache and become stuporous. Signs of meningitis usually make an early appearance. In other instances the first evidence is found in an infection of the wound. Occasionally a series of severe convulsive seizures indicate the change in condition. However, surprises are frequent. One sees recovery in those whose outlook appears hopeless; and, unfortunately, some patients appear to be on the high road to recovery for even a week or more after operation, when a fatal infection supervenes.

In cases that recover the improvement in functional disturbances that often occurs within the first week or two of operation is remarkable. Without entering into details, it may be said that sensory disturbances, aphasias, and defects in visual fields frequently subside completely; the majority of paralyses and pareses (except the type due to brain destruction) begin to improve before patients leave the front area hospital. It is well to reiterate here that paralyses or other losses of function making their first appearance or increasing directly after operation are evidences of damage inflicted by the surgeon. In a considerable operative experience I have not seen such manifestations, and cannot, therefore, accept the theory advanced by some that they are due to cerebral edema.

Even with rapid improvement in function or in the absence of functional loss patients should not be up and about for five weeks or more after operations for craniocerebral wounds. At best, headaches, blurred vision, pain in the wound, and giddiness on walking are common enough complaints in the earlier stages of convalescence.

In my experience very few complications developed after operation

in recovering cases. In view of the grave significance of hernia cerebri I wish to emphasize the fact that I *saw but one instance* of this complication after operation in my series of cases. This was a much soiled penetrating wound in which infection developed at the suture line in the dura. The rarity of hernia cerebri after the complete early operation that has been described should be one of the strongest arguments for the adoption of that technic. Epileptic seizures are described as not uncommon after operation, and of lesser and different significance than the epilepsy appearing as a late complication. I have seen only 2 cases in which epileptic attacks developed shortly after operation; both patients have remained free from recurrence of attacks up to the present time (September, 1919), one to two years since operation. The great majority of the wounds should heal by primary union. In the small number of scalp infections I saw the majority were slight and readily controlled. Frequently repeated inspections of and detailed care in the treatment of the wounds are important elements in successful results after operation. Later infections in the wound are of different significance, being referable to spicules of bone or other foreign matter that had been left behind.

Meningitis or cerebral suppuration after operation are fatal complications for which various therapeutic measures appeared to be of no avail.

Hernia cerebri as an early complication not infrequently recedes under proper treatment (*vide* p. 165). Such procedures as enlargement of the bony opening for supposed strangulation of the brain or ablation of the fungus are mentioned only to be condemned. All the evidence points clearly to infection, and infection alone, as the cause of hernia cerebri. The hernia cerebri is generally the result of an incomplete operation. The hernia varies in appearance and size from a superficially infected, slightly bulging, small area of brain surface, to a large sloughing mass. By the use of the Carrel-Dakin treatment or perhaps, preferably, dichloramin-T in oil, progressive sterilization of the hernial surface can often be attained and, with it, recession of the protrusion. The use of gravity, by propping up the patient's head, is said to be of value. But the most useful therapeutic measure, in addition to attempts at sterilization of the wound, is repeated lumbar puncture. This procedure had many advocates who saw no evidence that infection may spread as the result of evacuating cerebrospinal fluid. The fluid should be withdrawn slowly, and not in large amounts at one sitting, otherwise the hernia may sink back through the cranial defect, and the infection certainly be diffused. The lumbar puncture should always be done with the wound exposed to view so that changes in the hernia may be observed. In the later stages of hernia cerebri, as encountered in a base hospital, I have seen beneficial effects follow a subtemporal decompression.

Lumbar puncture is of value in the postoperative treatment of cranial wounds not only in hernia cerebri but also for the relief of intractible headache or other evidences of cerebral edema. I have, however, seen but few indications for its use in the recently wounded.

The **cause of death** after operations for craniocerebral wounds requires only brief comment. In the patients who die shortly after operation extensive brain destruction, sometimes due to ricochetting of the missile, is usually found. But autopsy shows infection to be the cause in the great majority of those who die at the front area hospital. In my series of cases suppuration was found not only in the brain and meninges but also invariably in ventricles that had been penetrated by missiles or bone fragments. Not a few of these patients were operated upon twenty-four hours or more after injury, so that there appears to be a definite relationship between fatal infections and the time after wounding at which operation is performed. It is difficult to make a more definite statement because the time at which the wound was sustained could not be determined in many of the serious cases.

Results of Operation for Recent Craniocerebral Wounds.—Little information can be derived from the voluminous literature on head wounds concerning other than the immediate or intermediate results of operation. Careful studies have been made of results noted after head wounds, but these have not been linked up with various operative measures that were employed or with the lesions encountered at operation. Since this chapter is, after all, essentially a commentary on the operative technic of craniocerebral wounds, I will detail the results of operation in my series of cases as based on follow-up reports. The latter have been received from the patients themselves, as well as from those under whose care patients subsequently came.

Before discussing the late functional results and complications the **mortality after operation** in these cases should be taken up. In general, the mortality from head wounds with intact dura is small with any technic that includes removal of the soiled wound and bone fragments. Occasionally, however, infection passes through an intact or bruised dura with fatal issue, so that here, too, the elimination of infective material by a properly conducted débridement is an important element in success. Among my cases death after wounds of the head with intact dura came as a result of other wounds. The usual mortality after operation for head wounds with dual penetration ranged from 50 to 60 per cent. in the different reports. By an examination of Cushing's figures, quoted at the beginning of the chapter, it will be seen that this mortality rate was strikingly lowered. A significant feature of the report was that his mortality in a first series of cases done in the older way was 54.5 per cent., and in a third series, with the improved operative technic, it was reduced to 28.8 per cent. Cushing's publication appeared too soon after the operations were performed to include possible subsequent deaths, so that the figures must be accepted for the mortality in the early weeks after operation. An important point is that deaths from any cause were included, even if unrelated to the head wound. This is the only basis upon which the mortality rates should be given, for there will be no general agreement on conditions that may be justifiably excluded. By paring and pruning, even with the utmost honesty,

attractive figures can be produced that will in no way represent the gravity of craniocerebral wounds.

The cases that were under my care fall into two series, the first (95 cases) operated upon in 1917, and the second (80 cases) in 1918. The great majority of deaths occurred in the first weeks, and not a few (certainly 5 per cent.) from other lesions. A number of the later deaths were definitely unrelated to the head wounds, as in a case in which death resulted from sepsis from a compound fracture, and post-mortem examination of the brain showed no evidence of infection. The mortality from every cause is, however, included in the following tabulation. It is based on reports received from one to two years since operation, and thus represents the mortality up to the present time. Follow-up reports were obtained in four-fifths of the cases of dural penetration.

	Percentage mortality first series, 95 cases.	Percentage mortality second series, 80 cases.
I. Scalp wounds	0	No cases
II. Cranial wounds—dura intact	8.5	6.2
(*a*) Simple fracture	6.6	No cases
(*b*) Depressed fracture	0	5
(*c*) Bursting fracture	100 (1 case)	25
III. Craniocerebral wounds—dura torn	42.5	29.4
(*a*) Depressed fracture	16.6	0
(*b*) Tangential wound	33.3	16
1. Ventricle intact	12.5	10
2. Ventricle penetrated by bone fragments	75	33.3
(*c*) Penetrating (metal retained)	30	34.3
1. Ventricle intact	25	20
2. Ventricle penetrated by missile	100	85.7
(*d*) Perforating	100	66.6

In the first series the technic of operation as described had not as yet been fully developed; the figures are sufficient commentary upon the difference in the results obtained. The results can be better interpreted if I add that a selection of cases was made possible when the second series were operated upon, and that only cases evidently or probably severe were chosen. This is seen in an analysis of the lesions in the 13 patients in the second series who died at the front area hospital: Ventricle penetrated by missile, 6 cases; perforating wound, 2 cases; multiple brain penetrations by missiles, 2 cases; penetration from vertex to base, 1 case; penetration complicated by gas infection of the brain, 2 cases.

The **late results** in the patients who recovered may now be discussed. The most impressive feature of the follow-up in both series of cases is that there is not a single report of late hernia cerebri, meningitis, or brain abscess. Since the great majority of these later complications are known to develop in the first six or nine months, it is reasonable to assume that they will certainly be at least very infrequent at this late date. Next in interest were the changes that occurred in paralyses and pareses. The improvement that took place in the first weeks after operation has already been noted. Reports received from time to time

show that this was continuous in a large proportion of the cases. So that at the present writing (September, 1919) the course of paralyses and pareses can be termed one ranging from progressive improvement to complete disappearance in the majority of cases. Spasticity and persistent paralysis were each reported twice. There was one case of persistent aphasia and two of permanent deficiencies in the visual fields. Epilepsy is considered the most common tardy manifestation after head wounds, yet up to the present there have been only three statements of its appearance. Two of the patients have petit mal and in neither was there a dural penetration; the third, suffering from generalized seizures, had a penetrating wound from which the foreign body was not recovered. The reports in 2 cases suggest that insanity may have developed; the dura had been penetrated and the foreign body retained in one, and the lesion was a slightly depressed fracture with intact dura in the other. Persistent headaches and dizziness of varying degrees were reported by fully 20 per cent. of the patients. Other subjective symptoms, such as insomnia, hypersusceptibility to sounds, inability to concentrate the mind, and so on, were also frequently mentioned, but these, like headache and dizziness, bear no proportionate relation to the gravity of the wound. Some of the patients have returned to former or other occupations, some are engaged in study, and only a small proportion (6 per cent.) appear to be permanently incapacitated as the result of head wounds. The conclusion that should be drawn from these follow-up reports is that the ultimate prognosis for patients with craniocerebral wounds after radical early operations is far more optimistic and cheering than seems generally thought to be the case.

The Treatment of Infected Craniocerebral Wounds.—The indications for and the methods of treatment of this class of cases are totally different from those for recent wounds. As already noted, the attempt to care for infected wounds in a similar manner led to disastrous consequences. Within twenty-four hours of the time of injury the wound may be definitely infected; wounds not operated on are almost certain to be infected by the time patients reach base hospitals. The indications for operation then vary within wide limits and no definite rules can be laid down. The neurologic manifestations and particularly the condition of the eye-grounds are often the decisive factors. Hernia cerebri or other infected lesions can often be successfully treated by the Carrel-Dakin or other non-operative methods for wound sterilization. If operation is decided on, it should be sharply limited to the area of infection, and equally limited to steps for the control of infection. Spreading infection and death may otherwise be the sequel. Loose bone fragments, bits of cloth, or other foreign material may have to be removed, and a purulent brain tract drained.

At best, the results were unsatisfactory in the cases I saw, whether or not secondary operations were performed. Neurologic manifestations and infection showed a tendency to persist and even to progress. The results were, of course, worse with dural penetration. If a hernia cerebri made its appearance the ultimate prognosis became bad, in my

experience. Although the hernia may have receded with persistent efforts at wound sterilization, I found, by following the course of these cases, that the hernia often meant either early acute infection of the brain or the focus in the brain for the later development of a brain abscess.

Late Complications and Sequels of Wounds of the Head and Their Treatment.—Final statements upon this very important aspect of the subject of head wounds cannot be made at the present time. Tuffier and Guillain[10] and Sargent and Holmes[9] have made studies of large groups of cases, analyzing the results without direct reference to the types of operative technic that had been employed. The following remarks are largely based on their observations.

Subjective symptoms, such as those already noted, are without gravity as far as life is concerned, but of great importance from the social viewpoint. I have stated that they bear no relation to the gravity of the wound, yet that does not indicate the significance of subjective symptoms. The size of the cranial defect is not a factor, for they are as common in small as in large breaches in the skull. Possibly a form of malingering in some cases, they appear in others to have a definitely organic origin as established by examination of the eye-grounds and the cerebrospinal fluid. Lumbar punctures often seem to have a favorable effect on subjective manifestations, especially on headache and vertigo. Subjective symptoms in themselves should never be the sole indication for a secondary operation such as cranioplasty or removal of a foreign body.

Organic Manifestations.—Destructive cerebral lesions produce results that, of course, vary widely, depending on their seat and extent. Details cannot here be given. The outcome of lesions of the frontal lobe appears to be favorable, even with large losses of substance; many of the patients suffer no mental disturbance. The improvement that often occurs after lesions in the sensorimotor cortex has already been described. Involvement of the pyramidal tracts usually results in permanent spastic paralyses. The prognosis of persistent aphasia is bad; although some improve, the great majority remain intellectually subnormal. Visual defects from lesions of the occipital lobe have a relatively favorable prognosis, the early symptoms showing a tendency to recede and the residual disturbances often were slight.

Serious mental disturbances are exceptional, and in some cases precise information concerning the antecedent history would have been necessary to establish the causal relationship between the wound and the psychosis. Insanity occurred in 0.64 per cent. of the 6664 cases in the statistics of Tuffier and Guillain.

Epileptic attacks comprise the most common late complication occurring in over 10 per cent. of the 6664 cases. They may make their first appearance anywhere from a few months to two years after the injury, and even more delayed first appearances may be recorded in the future. Generalized seizures are more common than petit mal. Epilepsy has followed wounds in which the dura and even the skull were

intact, as well as wounds with proved cerebral injury. Although lesions in the Rolandic area may be followed by epilepsy of the Jacksonian type, injury of the motor cortex as well as of other parts of the brain may result in generalized, non-focal seizures. The latter are, of course, of no aid in localizing the lesion. Occasionally epileptic attacks may be the first manifestation of an acute encephalitis or brain abscess.

Operation is not indicated in generalized epilepsy for the following reasons: There is no indication as to the region of the brain to be explored. The dura should not be opened at the site of the wound merely to divide adhesions that will almost certainly re-form; besides, such adhesions are commonly met in old brain wounds in patients who are not suffering from epilepsy. If the purpose of the operation is to reduce tension, other means, such as lumbar puncture or a subtemporal decompression, are more desirable. Repeated lumbar punctures appear to have a favorable effect on the number of attacks. An exploratory operation on the cicatrix is perhaps permissible if the attacks progressively increase in frequency and appear to be leading to permanent mental inferiority.

Jacksonian seizures offer a more favorable indication for operation. A few isolated focal attacks should not, however, lead to operative intervention, for they may be the result of an encephalitis that may clear up, or, in any event, cannot be relieved by operation. The presence of sequestra or a missile in the region of the motor cortex is the chief reason for operation in repeated Jacksonian seizures, and their removal may be followed by prolonged relief.

Late brain abscess occurred in a little over 1 per cent. of the cases, and is thus happily much rarer than would have been supposed. This grave complication is most commonly seen after wounds in which brain substance was exposed and in wounds that have suppurated. A tear in the dura had existed in almost all the reported cases. Too great emphasis cannot be placed on the evidence that the missile itself is not the principal cause of brain abscess; infection from sequestra, bits of cloth or other foreign material swept into the brain is the common etiology. In fact, abscesses about missiles are met in only a small proportion of the cases. The abscess is found at the site of the wound in the majority of cases, either in an existing hernia or in brain substance that has herniated. Abscesses in regions far removed from brain tracts are occasionally found. In 37 cases studied by Sargent and Holmes the overwhelming frequency of brain abscesses in the first three to six months after injury is shown; 28 patients developed abscesses in that period, whereas the complication appeared in the six to nine months' interval in 7 cases. The latest appearance of brain abscess was in the eighteenth month.

In some cases of brain abscess there are no indications of its development, and in others the course is an acute fulminating one, but in the great proportion of instances the usual symptoms and signs of brain abscess are gradually unfolded. These will not be recapitulated (see Keen's Surgery, Vol. III). An important point is that papilledema is

frequently absent. It is often difficult to make the differentiation between abscess and encephalitis. The value of regularly repeated careful neurologic examinations in patients with old craniocerebral wounds will be appreciated when one realizes that the reappearance of or increase in an old mono- or hemiplegia that was improving, or increase of an aphasia, may be indications of the development of a brain abscess or important localizing signs of the seat of the abscess.

Brain abscess unrelieved by *operation* is fatal; yet the vast majority of patients (97.5 per cent. in Sargent and Holmes' series) die after drainage of the pus. The least complicated procedures should be employed. The removal of a projectile or of sequestra in the abscess cavity is indicated, but the extent of dissection should be minimal under any circumstances if spreading infection is to be avoided. Subdural adhesions should not be disturbed. There may be a varying period of improvement following drainage of a brain abscess, but ventricular infection or further spread into the adjacent brain tissue with fatal issue are the common sequels. In my personal experience drainage of the abscess cavity has invariably been followed by death. On the other hand, there was one instance in which the patient has apparently remained free from recurrence for more than a year following *aspiration* of a deep-seated abscess. Such a procedure for brain abscess appears illogic at first sight, but several factors should be considered. The infecting organisms must be of low virulence in many cases. By aspiration of the pus collapse of the walls of the cavity is invited, or in rigid walled cavities a fresh exudation of bactericidal fluids. Drainage of a brain abscess frequently lights up the infection as a result of fresh paths that are laid open, and this appears to be almost inevitably the result, no matter what form of drainage is employed. Theoretically, then, superficially situated brain abscesses might better lend themselves to drainage; deep-seated abscesses, to aspiration. The abscess having been located, aspiration can be repeatedly performed if necessary. If drainage is to be employed, I believe a two-stage operation might be followed by less disastrous results. The first stage would consist in locating the abscess by aspiration, dissecting a tract to its site, and inserting a tube. Several days later the abscess would be entered and the drainage-tube inserted into the cavity.

Hernia cerebri is due to infection and generally masks an abscess or an area of encephalitis. Violent headache, high temperatures, torpor, and occasionally epileptic seizures precede its appearance. *Lumbar puncture should not be employed* in the acute phase, for it may be followed by spread of the infection. In the relatively favorable instances in which an encephalitis is the cause the protrusion may begin to recede in two or three weeks with one of the methods of wound sterilization; lumbar puncture aids in the reduction of the hernia under such circumstances. When an underlying brain abscess is the cause, this must, of course, be cared for. Excision or compression of the hernia or enlargement of the bony opening should be condemned. It may be necessary, however, to remove necrotic brain substance. In

some cases of persistent hernia with a low-grade infection contralateral decompression has been done with favorable results; I have seen one case in which striking improvement followed.

Late meningitis is the most fatal of the tardy complications after craniocerebral wounds, but is fortunately rare (0.48 per cent.). As a sequel to brain abscess it has already been noted. Meningitis may also result from fistulæ arising from necrotic bone or infected foreign material. In its localized form the condition exists as an encystic meningitis, and is characterized by cortical irritation and the signs of increased intracranial tension. Operation, consisting in drainage of meningeal collections of pus and the elimination of the foreign material, is occasionally successful. The generalized type of meningitis is exceedingly fatal, although occasional cures have been reported following frequent large lumbar punctures.

Encephalitis is a condition difficult to differentiate from brain abscess. It can sometimes be recognized when local cerebral symptoms arise from time to time, to recede spontaneously. In general, the symptoms are not as severe as in brain abscess. They are known to have receded after removal of bone fragments or other foreign material, but have also cleared up after negative exploratory operations. If encephalitis can be diagnosed, operation is not indicated.

Retained missiles in the brain do not in themselves comprise a late complication of head wounds, for a considerable proportion of the patients are free from symptoms. The question arises as to whether foreign bodies should be systematically removed in all cases. This is answered in the affirmative by those who hold that the foreign bodies are only apparently well tolerated, and that the patients are exposed to the possibilities of grave complications, such as brain abscess, or to sudden death. But Pierre Marie,[10] for example, has had under observation more than 80 cases of retained intracerebral projectiles in which there were absolutely no symptoms or signs referable to the foreign bodies. All the evidence at hand at the present time indicates that foreign bodies can be perfectly tolerated. Under such circumstances there should be no routine removal of retained missiles. The operation is not free from danger, and may result in the aggravation of existing disturbances in function, or the development of new neurologic manifestations. A lesion having been established, removal of the foreign body will not improve it.

Headache, vertigo, and other subjective symptoms are not indications for the removal of the foreign body. It should be removed if it is the probable cause of attacks of encephalitis or of a brain abscess. Lymphocytosis in the cerebrospinal fluid, associated with signs of increased intracranial tension, suggest the desirability of operation. The method of choice for the removal of foreign bodies is an approach through the cicatricial tissue occupying the former tract, and extraction with the electromagnet.

Cranial Defects and Their Repair.—Many papers have been written on the indications for cranioplasty, and more on the technic to

be employed. The confusion that exists on this subject will not be cleared up until the sequelæ with and without operation are better known than at the present time. Such symptoms as headache, vertigo, and even epileptic attacks are considered indications for cranioplasty by some, and these very symptoms are contraindications to operation for others. In a study of a number of cases operated on Marie found improvement in subjective symptoms in some, no relief in a larger number, and aggravation of the manifestations in others. Even new symptoms are reported to have developed after operation. Under such circumstances a clear therapeutic indication for cranioplasty cannot be said to exist at the present time.

Cranioplasty may, however, be indicated for protection of the brain and for esthetic reasons; the latter is particularly true for large skull defects in the frontal region. An operation should not be performed until the wound has been healed for several months. Any symptoms that indicate the possibility of a late complication are contraindications; if such manifestations have already appeared, the operation is not justified, even though they are, for the time being, in the background. The cerebrospinal fluid and eye-grounds should show no evidence of increased intracranial tension.

Many types of operation have been performed for the repair of cranial defects, and good results have been reported after all of them. A description of the various operative procedures cannot be here given. They may be classified as follows:[5]

A. Cranioplasty, which is, strictly speaking, a procedure consisting in plastic flaps fashioned from the skull itself.

B. Bone-grafts, auto-, homo-, or heteroplastic, with or without periosteum.

C. Grafts of decalcified or macerated bone.

D. Cartilage grafts.

E. Osteocartilaginous grafts.

F. Prostheses of gold, platinum, silver, or ivory.

Cranioplasty, either of the Mueller-Koenig variety or one of its modifications, is only suitable for the smaller defects. It cannot be employed in the frontal region because of the additional scarring that results. Autoplastic bone and cartilage grafts are most widely used; excellent results have been described after both. Villandre,[11] who has had a large experience, reports 100 per cent. success with osteoperiosteal grafts taken from the tibia, and 96.8 per cent. with rib-cartilage transplants. It is as yet too soon to make any definite statements concerning the ultimate fate of such autotransplants.

Application of the Experiences in Craniocerebral War Wounds to Head Injuries and Other Intracranial Lesions in Civil Life.—Cranial injuries with extrusion of brain substance are rarely seen in civil practice, but depressed fractures with or without dural puncture and brain damage are not at all uncommon. A soiled scalp wound is often present in such deeper injuries. It is for these cases that the operative technic as described for gunshot wounds has its main indica-

tion in head wounds in civil life. The operation heretofore practised has generally consisted in incision, piecemeal removal of depressed fragments of bone, removal of spicules from the brain, and institution of drainage. The results have, on the whole, been unsatisfactory. I have recently seen 2 cases in which brain abscess followed such operations. There is every reason to believe that a great stride forward will be made in the treatment of soiled craniocerebral wounds of civil life when the technic developed for gunshot wounds shall have been applied with the same meticulous attention to details. On the other hand, it would manifestly be a grave mistake to consider cerebral penetrations by small calibered, relatively low explosive bullets of civil life in the same category with the injuries caused by war projectiles. In the former case relatively little foreign material is swept into the brain by the missile, the wound of the scalp is generally a non-soiled, punctured lesion, and thus the indications for a débridement of the tract do not exist in the vast majority of instances. Our knowledge as to the surgical treatment of complications encountered at operation has also been enhanced, and this has its direct application not only in traumatic surgery but also in cranial operations for other conditions. The more logical methods of treatment of late complications of head wounds (epilepsy, hernia cerebri, etc.), evolved during the war, should improve the results in similar lesions encountered in civil practice. Indications for and methods of repair of dural defects were developed; they will probably have a wider application in cranial operations for other conditions (see page 183) than fractures. The indications for extraction of intracerebral projectiles and for repair of cranial defects have been more clearly defined, and the technic of operation greatly developed. Finally, the many advantages in conducting cranial operations under local anesthesia, demonstrated during the war, will undoubtedly be recognized as existing to a similar extent in cranial operations in civil life (see page 180), and thus an important lasting addition to the technic will have been made.

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HYDROCEPHALUS IN INFANCY AND EARLY CHILDHOOD

During the past few years our conception of hydrocephalus has been converted from a vague groping among ill-understood phenomena to a clearly defined comprehension of the etiology and pathology of the condition. This has been arrived at through the studies of Petit and Girard,[10] Dixon and Halliburton,[6] and others, but chiefly through the brilliant experimental and clinical work of Dandy and Blackfan.[1]

The reason for failures and resulting pessimism concerning the disease has been that the cause of hydrocephalus having been undetermined, treatment has been empirically directed toward the effects of the disease—drainage of the accumulated fluid. With the tremendous impetus to further investigation that should result from recent studies there is much reason to feel confident that real advances in the treatment of hydrocephalus will be made in the near future.

Etiology and Pathology.—An understanding of the source, the normal paths of escape and absorption of the cerebrospinal fluid is necessary to comprehend the development of hydrocephalus. Briefly, the source of cerebrospinal fluid is definitely proved to be the choroid plexuses of the ventricles, the lining ependyma of the ventricles contributing little if at all to the formation of the fluid. The fluid leaves the ventricular system through the basilar foramina of Magendie and Luschka, to enter the cisterns grouped about the midbrain and cerebellum. These cisterns, variously termed according to their anatomic relationship to different parts of the brain, are really a single collecting system from which the cerebrospinal fluid escapes to the entire subarachnoid space. Absorption of the fluid takes place throughout the subarachnoid space, but chiefly over the cerebral cortex; there is no evidence that the pacchionian bodies or the supposed stomata near the longitudinal sinus play any important rôle in absorption.

Hydrocephalus results either from increased production of cerebrospinal fluid or from diminished absorption. We will here concern ourselves almost exclusively with that due to diminished absorption. This, the common variety in infancy (so often termed "idiopathic" in the past), is invariably due to obstruction. Depending upon the site of the obstruction, different terms are applied. Those now generally employed are: "obstructive," when the block to the escape of fluid is in the ventricular system (generally at the foramina), and "communicating," when the obstruction, located in the subarachnoid spaces, shuts off the cisterns. These terms are rather misleading, for obstruction always exists. In the tabulation and in the following discussion the terms "*ventricular obstructive hydrocephalus*" and "*subarachnoid obstructive hydrocephalus*" are substituted as offering a clearer picture of the seat of the pathologic condition. Both types occur with about equal frequency and, clinically, they are indistinguishable. Furthermore,

they may overlap, for adhesions following meningitis may seal the foramina of exit from the ventricles and at the same time obliterate the cisterns. However, the two conditions can usually be sharply differentiated by the tests to be described. Their differentiation is of the greatest practical importance, for the treatment of the one is totally different from that of the other.

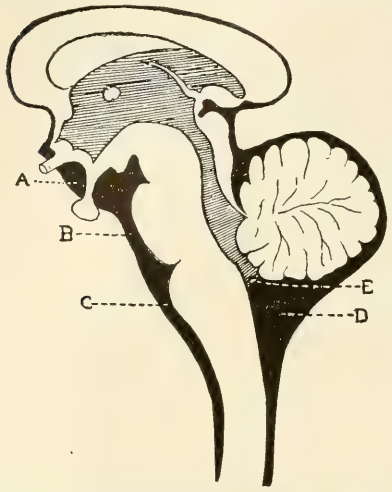

FIG. 149.—DIAGRAM REPRESENTING THE MIDSAGITTAL VIEW OF THE BRAIN STEM, SHOWING THE VENTRICULAR SYSTEM (IN CROSS LINES) AND THE SUBARACHNOID SYSTEM (IN BLACK).

The communication between the two systems is at E (foramen of Magendie). The foramina of Luschka are not shown. *A*, Cisterna interpeduncularis; *B*, cisterna pontis; *C*, *D*, cisterna cerebellomedullaris (cisterna magna). (Dandy and Blackfan.)

In *subarachnoid obstructive hydrocephalus* the obstruction has been found to be due to adhesions in all the cases that have come to postmortem examination (Dandy[4]), so that adhesions due either to a pre- or a postnatal meningitis may be considered the common cause of the condition. To produce sufficient cisternal obstruction for the development of hydrocephalus it is evident that a fairly wide meningeal area must be involved, and it is difficult to conceive how this can be of other than inflammatory origin. The majority of the cases of ventricular obstructive hydrocephalus in infancy have up to the present also been found due to adhesions shutting off the foramina of Luschka and Majendie; but there has been an appreciable percentage of congenital malformations obliterating the aqueduct of Sylvius or other intraventicular channels.

- Hydrocephalus due to
  - Diminished absorption of cerebrospinal fluid
    - *Subarachnoid obstructive hydrocephalus* (adhesions in the subarachnoid space).
    - *Ventricular obstructive hydrocephalus* due to
      1. Congenital atresias.
      2. Adhesions at the foramina of exit.
      3. Tumors blocking the ventricular system directly or through increased intracranial pressure.
  - Increased production of cerebrospinal fluid
    - Acute hydrocephalus (meningitis and trauma).
    - Ventricular hydrocephalus from occlusion of vein of Galen.

Hydrocephalus secondary to neoplasms need only be mentioned in passing in a discussion centering on the hydrocephalus of infancy, for tumors are exceedingly rare at this age. In childhood and adult life neoplasms are, of course, the most common cause of hydrocephalus, producing the **ventricular obstructive type.** "External hydrocephalus" is not mentioned in the tabulation, for its clinical entity has not as yet been proved. A rare finding at operation or autopsy, the condition seems to be due to the ordinary (internal) hydrocephalus with escape

of cerebrospinal fluid over the cortex from shrinkage of the cerebrum and the formation of artificial channels. Hydrocephalus due to increased production of cerebrospinal fluid will also merely be mentioned. In meningitis there is an increased production of fluid, but its source is probably more external than internal; the same may be said of the overproduction of cerebrospinal fluid encountered in head injuries. These conditions are not comparable with true hydrocephalus. On the other hand, true hydrocephalus does result from increased production of cerebrospinal fluid in thrombosis of the vena magna of Galen, a venous stasis resulting from inadequate collateral circulation. The condition is rarely seen.

The pathologic changes that result from hydrocephalus are described in Volume III of Keen's Surgery. Solid support of the various statements made as to the causation of hydrocephalus has recently been given in additional experimental work by Dandy.[4] He has produced

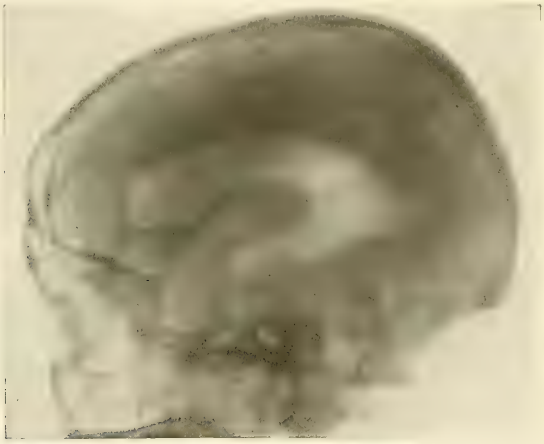

Fig. 150.—Ventriculogram of the Right Lateral Ventricle Indicating an Approximately Normal Ventricle. (Kindness of Dr. Walter E. Dandy and of "Surgery, Gynecology, and Obstetrics.")

hydrocephalus by plugging the aqueduct of Sylvius, and a unilateral hydrocephalus by closing off the foramen of Monro. Collapse and obliteration of the ventricle occurred when one foramen of Monro was blocked and the choroid plexus of the corresponding lateral ventricle was excised. This finally establishes the origin of the cerebrospinal fluid from the choroid plexus. At the same time the experiments demonstrate the mechanism of production of ventricular obstructive hydrocephalus. The picture of subarachnoid obstructive hydrocephalus was also produced by passing a thin gauze band about the midbrain, the cisterns being the principal structures shut off as a result of this procedure.

Diagnosis.—The **differential diagnosis between the two principal types of obstructive hydrocephalus** cannot be made by physical examination, the clinical picture being identical in both. Since the treatment for the two conditions is, as has been said, entirely different, it is ab-

solutely essential to distinguish between them. Lumbar puncture by itself can occasionally make the differentiation, but the evidence therefrom may be misleading. The differentiation can be made with certainty by the phenolsulphonephthalein test. It is important to note that the ordinary solutions of this dye are alkaline and their injection may be followed by severe reactions; *only freshly prepared neutral solutions are to be employed.* The dye normally appears in fluid obtained by lumbar puncture in from one to three minutes after it has been injected into a ventricle. In ventricular obstructive hydrocephalus the dye will not appear in the spinal fluid for an hour or two, and often only in traces for several hours, or even days. On the other hand, since the communication with the spinal spaces is free in subarachnoid obstructive hydrocephalus, the dyestuff here appears as promptly, or almost as promptly, as in a normal individual. The test is simple, decisive, and free from danger *if the phenolsulphonephthalein solution is properly prepared.* For the practical purpose of differentiation between the two types of hydrocephalus this test suffices. However, to appreciate that the underlying cause of the hydrocephalus is diminished absorption in both instances, quantitative estimation of the amounts of dyestuff excreted in the urine may be made. The normal two-hour output of the dye after intraventricular injection is 12 to 20 per cent.; in ventricular obstructive hydrocephalus it is practically nil, and ranges between 2 and 5 per cent. in subarachnoid obstructive hydrocephalus. The striking difference between the two types of hydrocephalus can be demonstrated by the intraspinal injection of phenolsulphonephthalein. The normal excretion of the dye by the kidneys after intraspinal injection is from 35 to 60 per cent. This figure is approximated in ventricular obstructive hydrocephalus because there is no block beyond the foraminal exits of the ventricular system. In subarachnoid obstructive hydrocephalus, on the other hand, the average two-hour absorption is only 10 per cent.

Ventriculography.—In addition to the phenolsulphonephthalein test of Dandy and Blackfan, Dandy has very recently investigated hydrocephalus by roentgenography after the *injection of air into the ventricles.*[2] With this method the diagnosis of hydrocephalus in its early stages can be made, and, in addition, the degree and extent of thinning of brain cortex can be determined. With the addition of fluoroscopy the paths along which the air passed could be followed, and the exact situation of obstructions fixed, in several instances. A reaction occurred in one of the 20 cases in which ventriculography with air injection was practised, but relief followed the release of the air by ventricular puncture. The method has only been employed in hydrocephalic children, but offers possibilities for the localization of tumors that indent or displace the ventricles. The lateral ventricles are always sharply outlined in the roentgenograms in children and should be as well defined in adults. The technic of air injection is simple. The ventricle is entered through an open anterior fontanel or through a trephine opening if the fontanel is closed. Cerebrospinal fluid is

withdrawn and accurately replaced by the same amount of air. A two-way stop-cock attached to the syringe is essential for this purpose. Twenty c.c. of fluid is withdrawn at a time, and the replacement continued until all the accessible fluid is removed.

A further development in the study of hydrocephalus introduced by Dandy[5] consists in roentgenography after the intraspinous injection of air. After all, only limited information concerning the site of obstruction can be obtained by intraventricular injection of air, for the air will only reach as far as the first block and will not show the extent of the obstruction. By intraspinal injection of air an obstruction anywhere in the subarachnoid system will be indicated. The determination of the potency or obliteration of the cisterns will prove of invaluable aid, I believe, in the future treatment of hydrocephalus. The method

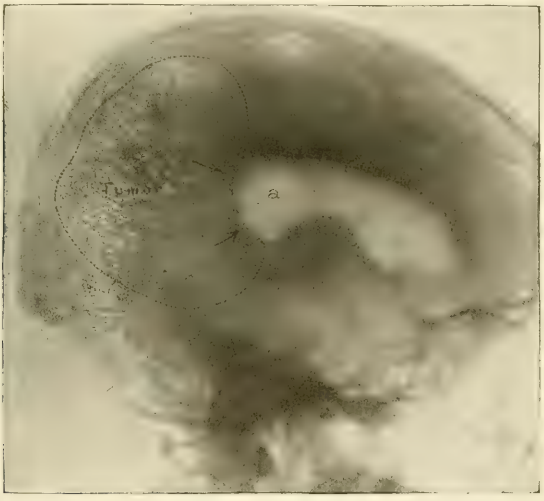

FIG. 151.—VENTRICULOGRAM OF THE LEFT LATERAL VENTRICLE ENDING ABRUPTLY AT *a*, ABOUT THE MIDDLE OF THE BODY.
The size and situation of the tumor as found at operation are indicated. (Kindness of Dr. Walter E. Dandy and of "Surgery, Gynecology, and Obstetrics.")

may as well prove of considerable value in the localization of brain tumors or other central lesions, but spinal puncture with air replacement is, of course, contraindicated in brain tumor unless the intracranial pressure has been relieved.

In intraspinal injections of air or fluid the ventricular system is eliminated, the air or fluid flowing directly into the cisterns and thence into the subarachnoid spaces over the brain surface. These spaces being deeper over the sulci, the latter would be more clearly indicated in the roentgenogram. In some experimental work I was able to show that the cerebral and cerebellar sulci were clearly outlined in the *x*-ray picture after the intraspinal injection of small quantities of collargol, and suggested the method as a basis for the graphic study of the human brain cortex. Dandy, by employing air, achieved the same results without any harmful sequelæ; only additional experience will show if

the procedure is entirely free from danger. He used intraspinal injection of air in 8 patients, transient headache and vomiting occurring in 2 cases, no symptoms in the others. In the single instance in which I employed spinal injection of air, severe headache, vomiting, and some

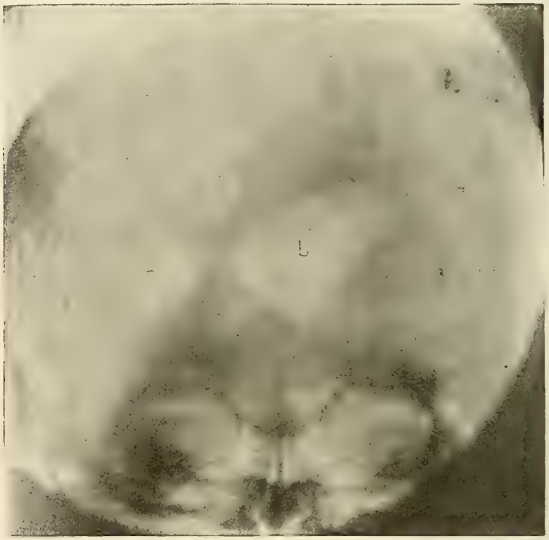

FIG. 152.—ANTEROPOSTERIOR VENTRICULOGRAM SHOWING THE LEFT VENTRICLE, *b*, PUSHED TOWARD THE RIGHT BEYOND THE MEDIAN LINE, AND THE RIGHT VENTRICLE, *a*, ALSO DISLOCATED TO THE RIGHT. (Kindness of Dr. Walter E. Dandy and of "Surgery, Gynecology, and Obstetrics.")

collapse followed the introduction of 80 c.c., the patient recovering in about an hour. The term "air injection" is misleading; a better expression would be "air replacement," for the essential part of the tech-

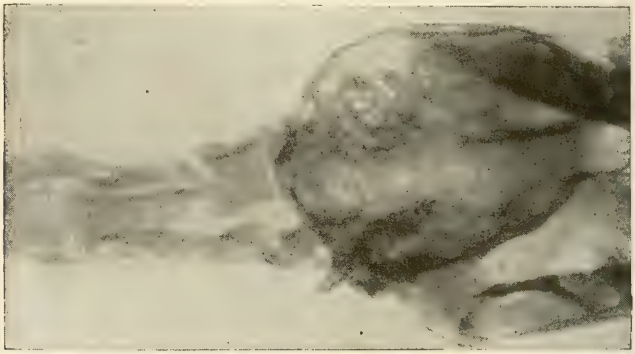

FIG. 153.—ROENTGENOGRAPH SHOWING OUTLINES OF CEREBRAL AND CEREBELLAR SULCI AND OF SPINAL SUBARACHNOID SPACE VIEWED FROM ABOVE IN A DOG AFTER THE INTRASPINAL INJECTION OF COLLARGOL.

nic consists in accurate replacement of cerebrospinal fluid by the same amount of air. A two-way stop-cock is used as in intraventricular injection, and the fluid is replaced by air until all fluid is withdrawn. The maximum amount of air injected by Dandy was 120 c.c. The

position of the patient for the lumbar puncture and air replacement should be one in which the head is at least 20 degrees higher than the needle. The roentgenogram after intraspinal air replacement in a normal individual shows the cisterns at the base of the brain and the ramifications of the subarachnoid spaces along the sulci. A number of plates from various angles must be taken to obtain the composite picture. In 3 cases Dandy was able to determine exactly the seat of obstruction in the cisternal system after other methods had failed.

FIG. 154.—A RETOUCHED PHOTOGRAPH OF A ROENTGENOGRAM OF THE HEAD AFTER AN INTRASPINOUS INJECTION OF AIR.

The subarachnoid space is probably normal. The lines of the component parts of the subarachnoid space have been intensified because of loss of detail through photographic reproduction. *A*, Cisterna interpeduncularis; from it many large branches can be seen establishing direct communication with the central sulci; *B*, cisterna shadow subdued by the dense temporal bones. This part of the cisterna can be seen in many *x*-rays; *C*, cisterna magna, from it the cerebellar subarachnoid space completely encircles the cerebellum, *D*. (Dandy.)

Treatment.—Although spontaneous recovery in hydrocephalus may occur, presumably from absorption or rupture of adhesions, such a happy outcome, unfortunately, is very infrequent, and the great majority of the cases progress to a fatal issue. Any treatment, no matter how heroic, that offers a logical possibility of cure or even relief therefore deserves earnest consideration. Now that the pathology of hydrocephalus has been grasped and the mechanism of its production appreciated, the empiric methods that have been employed in its treatment must be discarded.

Treatment of Subarachnoid Obstructive Hydrocephalus.—Operative treatment in the past has consisted in attempted drainage of the ventricles toward the cerebral cortex or scalp, the drainage of the spinal subarachnoid space into the retroperitoneal tissues or peritoneal cavity, or drainage into the venous system directly or by vein transplants. For manifest reasons these various methods have not had any measure of success. In 1915 Frazier and Peet[7] demonstrated that thyroid extract, in contradistinction to other organic extracts, has a specific inhibitory action upon the production of cerebrospinal fluid. On the basis of their investigations thyroid feeding has been employed in the treatment of subarachnoid obstructive hydrocephalus, and prom-

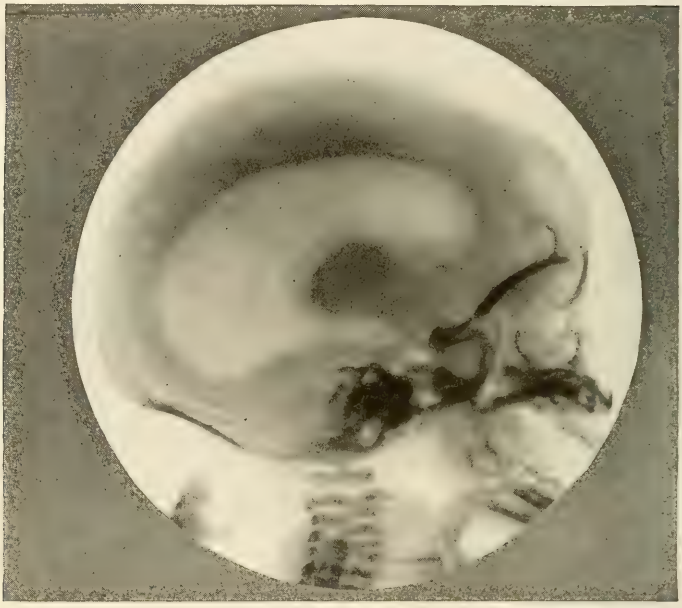

FIG. 155.—VENTRICULOGRAM OF MODERATELY DISTENDED VENTRICLE IN VENTRICULAR HYDROCEPHALUS.

The size of the head is normal. Note the obliteration of normal contours, the posterior horn making a diffusely bulging shadow. The deeper shadow in the anterior part of the ventricle is due to air in the opposite ventricle. (Dandy.)

ising results have been reported. Manifestly, such therapy can have no effect on the existing obstruction, and it is difficult to picture a cure of the condition by this means. However, it is possible that the reduced area of absorption in this type of obstructive hydrocephalus may suffice to carry off adequately the ventricular fluid reduced in amount by the administration of thyroid.

In 1918 Dandy approached the problem from a different angle.[3] He proposed an operation consisting in the excision of the choroid plexuses of both lateral ventricles. This appears an astounding procedure to advocate, but it is also a logical outcome of the experimental and clinical investigations of the subject. Surgical measures at the present time being incapable of removing the cause—cisternal obstruc-

tion—of the type of hydrocephalus in question, the source of the fluid is itself attacked. The absorption rate of fluid in subarachnoid obstructive hydrocephalus is approximately only one-fifth of the normal. By removal of the choroid plexuses of both lateral ventricles about four-fifths of the total amount of the fluid-forming structure is eliminated. The operation consists in making a small bone-flap over the parietal eminence, well posterior to the Rolandic area. Cortical vessels along the line of the planned incision having been ligated, the cortex is incised into the ventricle. The lips of the opening are held apart by a nasal dilator, or, when the ventricle is very large, by suitable retractors. All the ventricular fluid must be evacuated to clearly see the choroid plexus from the foramen of Monro to the tip of the descending horn. The plexus is lifted at the former point, the vessels clamped off here with a small silver clip, and after proximal clamping and division of the plexus, it is stripped from its narrow attachment to the ventricle until the middle of the floor of the ventricle is reached. A pledget of moist cotton is inserted into the foramen of Monro to prevent blood entering the third ventricle. Similarly, the plexus is picked up from the tip of the descending horn and stripped to the middle. Finally, its attachment here is liberated and the plexus removed. Bleeding from denuded areas is readily controlled by moist cotton pledgets, and special care must be taken to leave no bleeding points. In advanced cases of hydrocephalus the enormous collapsed cavity is filled with saline solution before closure of the cortex. The latter, dura, and scalp are carefully approximated by interrupted silk sutures. Dandy has performed this operation in 4 cases of hydrocephalus. Three died in from two to four weeks after operation, the fourth is apparently well ten months after operation. This is the only one that had a bilateral extirpation of the plexus, and, significantly enough, the only one in which the hydrocephalus was not extreme at the time of operation. There is little reason for attempting the cure of hydrocephalus when brain destruction is advanced. The choice of an operation of this type, should it prove to be followed by satisfactory results, will thus always require well-balanced clinical judgment in the selection of suitable early cases.

Treatment of Ventricular Obstructive Hydrocephalus.—It is evident from the description of the pathology of this variety that any attempt at a radical cure must consist in the removal or side-tracking of the obstruction. When the latter exists at the foraminal exits it is conceivable that a feasible operation can be performed, consisting in puncture and canalization at the sealed-off foramen of Magendie. No such operation has as yet been practised, but there is logically enough reason to feel that it offers a likelihood of success and will undoubtedly be attempted.* When the obstruction in the ventricular system is

* In a recent personal communication from Dandy he states that since publishing his papers he has had some splendid results in all types of obstructive hydrocephalus, including obstructions at the foramina of Luschka and Magendie and in the aqueduct of Sylvius.

anterior to the foraminal exits or to the iter, there seems little surgical possibility for its radical cure at the present time.

Puncture of the corpus callosum, first described by von Brammann,[9] was proposed by him for the cure of ventricular obstructive hydrocephalus. It was thought that by this operation a permanent pathway would be made for the escape of ventricular fluid to the subdural space. This has not been shown to exist; in fact, the tract has been described as closing within a few weeks of operation. Even assuming its patency, it is not apparent how there can be much absorption of ventricular fluid from the poorly vascularized subdural spaces. Albeit, though difficult to understand, there are some reports in the literature that go to show

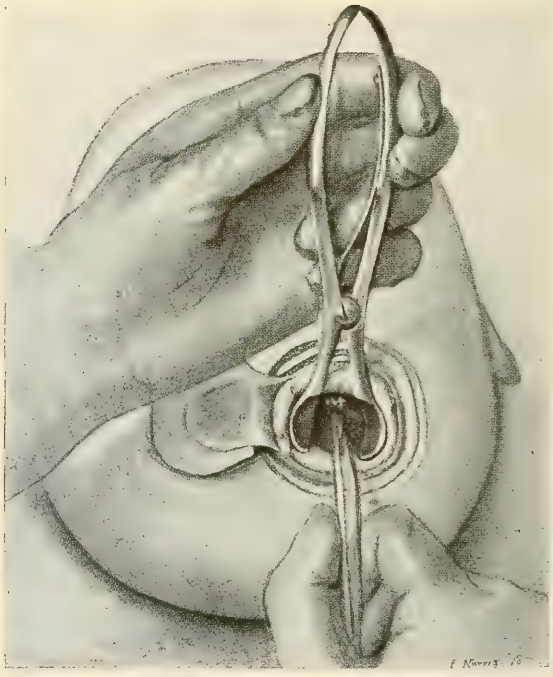

Fig. 156.—The Opening in the Cortex is Maintained by a Nasal Dilator. The fluid has been entirely removed from the ventricle to permit exposure of the choroid plexus shown in the grasp of the forceps. (Dandy, in "Annals of Surgery.")

that puncture of the corpus callosum, as ordinarily practised, may be followed by excellent results and even by cure. If, on the other hand, permanent drainage into the *subarachnoid* space could be established, such a procedure would be an ideal one for the cure of ventricular obstructive hydrocephalus.

The technic of *puncture of the corpus callosum* is simple. If the anterior fontanel is not widely open a small trephine opening is made a short distance to one side of the situation of the longitudinal sinus and directly behind the coronal suture. An opening is made in the dura sufficiently large to admit the blunt end of the specially devised flexible silver cannula. This, bent to an appropriate angle, is gently

passed over the cortex and then downward along the falx cerebri. Its downward direction should be maintained; otherwise there must be absolutely no force employed in the manipulations, the cannula descending practically by its own weight. At a variable depth, depending on the age of the patient and the extent of the hydrocephalus, but averaging some 6 cm., the resistance of the corpus callosum is encountered. The cannula passes through this with very little effort and the ventricle is entered. By gently rocking the instrument back and forth the opening in the corpus callosum is widened. The cannula is then withdrawn in the path of its introduction before there is excessive escape of ventricular fluid. One or two silk sutures suffice to close the incision in the dura, the button of bone is replaced, and the scalp sutured.

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RECENT ADVANCES IN THE TREATMENT OF BRAIN TUMORS

The surgical treatment of brain tumors has not made the rapid advances anticipated ten years ago. Indeed, the general impression appears to be that very slight, if any, progress has been made in the operative therapy of tumors of the brain. The statistical reports of Tooth,[3] Von Eiselsberg and Ranzi,[6] and Krause,[3] in 1913, giving very high operative mortalities, went far to establish this pessimistic viewpoint, especially because the end-results in many recovered cases appeared about as bad whether or not attempts at radical removal of tumors were made. That the well-established operation of subtemporal decompression effectively relieves headache and other symptoms, and often saves vision, is now universally accepted; but beyond this the prevalent belief seems to be that operations for brain tumor offer the gloomiest outlook, both immediate and distant.

Nothing could be further from the truth. In the first place, the operative mortality in brain tumor operations has fallen steadily in the hands of those who have employed the required precautions and have observed the necessary refinements in technic, until the figure has reached as low as 7 or 8 per cent.; and there is every reason to think it will drop considerably below that. A significant evolution is the lowering of the mortality after radical or attempted radical operations to a figure below that of decompression for unlocalized and advanced

growths. Another encouraging feature is that, with improving diagnostic methods,[3] a progressively increasing percentage of tumors are found at operation in the regions in which they are localized.

The results of operations for brain tumor have been grouped in various ways. The best reported figures are those of Cushing[1] based on 136 operations. The operative mortality was 7.3 per cent. A point of great interest is the fact that meningitis as a postoperative factor was eliminated; meningitis developed in a single instance in the series, as compared with 10 or 11 per cent. in a large series of cases reported by others only a few years before. Recovery in the true sense occurred in about 5 per cent. of the cases, recovery with some persistence of symptoms in 10 per cent., and alleviation of symptoms, including improvement of vision and prolongation of life, in 50 to 60 per cent. However, there will be little appreciation of any progress made in the treatment of brain tumor until those who report individual cases or small or large series of cases "talk the same language." Almost all the reported statistics in the literature are without any value because all varieties of cases are thrown together more or less indiscriminately, there is no definite understanding of what is meant by cure, by relief of symptoms, and so on. When, for example, claims are made for the advantage of a certain technic how can they be weighed in the absence of any scale for comparison? There must be a comprehensive schedule for history analysis, operation and postoperative course, follow-up, and all cases should be reported in accordance with such a schedule.

Limited space will not permit a detailed consideration of many underlying principles and technical procedures that have been factors in the improvement in the results of brain tumor operations. Certain features and types of operations that have been developed will be taken up.

Team Work and Time.—At best, the usual cranial operation is a prolonged procedure, involving, as it does, the utmost care in the opening of the skull, the treatment of exposed dura, brain, and the lesion itself, and in closure of the wound. Although no brief is held for the saving of time as such, at the expense of delicacy of manipulations or other essentials, all time-saving methods that sacrifice nothing mean much to the patient. Using the assistants at operation to the maximal degree is such a method. Thus, at the New York Neurological Hospital, the operator will pass a scalp hemostatic suture along one of the three sides of a planned osteoplastic flap, his two assistants placing the suture along the other two sides; trephine openings will be simultaneously made by surgeon and assistants, and all three will be engaged in passing and tying the numerous sutures necessary for wound closure. Many other ways in which real team work can be employed for the benefit of the patient will occur to those who will give the matter consideration.

Anesthesia.—In the past year I have performed almost all cranial operations, including osteoplastic flaps and the more difficult suboccipital craniectomy, under local anesthesia. It offers many ad-

vantages and should prove to be the anesthesia of choice, I believe, except in unruly and highly nervous individuals, or in the very young. The scalp incision is rendered bloodless or nearly so. Congestion and increased tension ordinarily accompany inhalation narcosis. Being absent with local anesthesia, there is less bleeding and oozing from bone, dural and cerebral vessels, and from cerebral tissues. For the same reason intracerebral tension is less. In a recent case of infiltrating glioma exposed at a subtemporal decompression under local anesthesia, I was impressed by the absence of any rupture of the cortex, whereas that complication was anticipated. The patient's head can be placed in the exact position that is desired and shifted as required. Inadvertent rough manipulations, always producing some shock (although the patient cannot say so under general anesthesia), will not be inflicted in operations under local anesthesia. Finally, operations under local anesthesia are attended by less shock, and postoperative complications due to inhalation narcosis are avoided. One per cent. novocain solution in adrenalin (15 drops to 30 c.c.) is employed for the scalp. This is freely injected along the lines and in the planes of the proposed incision; if large amounts are required, a $\frac{1}{2}$ per cent. solution of novocain may be employed after the scalp has been anesthetized. The dura requires no infiltration of novocain, being insensitive when not inflamed.

For general anesthesia ether narcosis is safest. Several years ago its administration by the intratracheal method of Meltzer was used in not a few brain operations, but that method is now supplanted by intrapharyngeal anesthesia. For brain surgery the latter offers all the advantages with none of the drawbacks of the intratracheal method of anesthesia.

Treatment of Hemorrhage.—Most surgeons, I believe, have abandoned the use of the tourniquet for the prevention of bleeding from the scalp. By a well-placed hemostatic suture about the area for the proposed osteoplastic flap bleeding is completely or almost completely controlled. The preliminary ligation of dural vessels on both sides of the planned incision of the dura will render its incision bloodless. The same method will give similar results in incision of the cerebral cortex. Cushing's silver clips are invaluable when vessels are not readily accessible for transfixion by suture. Bleeding from the brain substance is usually readily controlled by pledgets of moist or dry absorbent cotton. Ligatures may be required, but, as frequently happens, hemorrhage will promptly cease upon application of a bit of muscle (or fascia, if muscle is not accessible in the wound) to the bleeding area. The latter method is generally efficacious for hemorrhage from an injured sinus, although ligature may here, too, be required.

Treatment of Increased Intracranial Tension Encountered at Operation.—Tension met at operation is not infrequently so great that exploration of the brain or subsequent closure of the dura is impossible unless some method is employed for its reduction. The following is a consideration of the procedures that are applicable in either instance.

Some years ago perhaps the most favored method was lumbar puncture. Its dangers have been amply demonstrated, I believe, so that lumbar puncture should now rarely be employed. It may be necessary, however, if one or more of the following methods for lowering tension fail. The simplest means of reducing tension consists in making a small opening in the dura exposed at operation and introducing a grooved director. The instrument is carefully shifted in various directions, thus permitting subarachnoid fluid to escape. After the dura has been opened and excessive tension is found to be present a similar result may be obtained by pricking the pia-arachnoid in a number of places; fluid escapes freely and the flow may be accelerated by gentle pressure. With greatly increased tension these manipulations do not often succeed, and one must resort to ventricular puncture. The site of election (the midportion of the temporal lobe) is generally exposed at operation; with a good working knowledge of the anatomy of the ventricles, tapping of the body or one of the horns should be possible through any exposed portion of the brain. If the operative exposure is near the median line puncture of the corpus callosum may be practised, partly for the immediate effects and partly for the supposed more distant results on the secondary hydrocephalus (see p. 178). When dilatation of the ventricle on the exposed side is associated with increased intracranial tension, ventricular puncture is very efficacious. In the absence of hydrocephalus, however, excessive tension must be dealt with, in operations over the cerebral lobes, by subtemporal decompression. The temporal muscle is generally part of the pedicle of an osteoplastic flap, so that the decompression is very readily accomplished by rongeuring a semicircle of bone from the base of the flap, removal of a similar area of temporal bone well into the fossa (the necessary exposure is obtained by stripping away and retracting the temporal muscle and pericranium), and making the usual incisions through the dura. Maximal decompression follows the operation performed on the same side of the head as the brain lesion. However, it is inadvisable to decompress at the base of a left-sided flap, because aphasia, unfortunately, has resulted even when the defect was carefully made deep in the temporal fossa. So that a right-sided decompression must be performed to obtain relief from pressure in left-sided craniotomies if ventricular puncture fails. Puncture of the cisterns is a special method for reducing tension in operations in the posterior fossa, and will be subquently described.

Some very interesting experimental studies have recently been made by Weed and McKibben that appear to strike to the very root of the problem of increased intracranial tension. Although their work can be but briefly noted here, it should be realized that it may have far-reaching results not only in the treatment of increased tension in brain tumors but also in hydrocephalus, injuries of the brain, and in other cerebral conditions. Weed and McKibben have shown that intravenous injections of even small amounts of hypertonic solutions (30 per cent. sodium chlorid) are followed by marked and sustained fall in pressure of cerebrospinal fluid, together with pronounced shrinkage of the brain.

Exactly opposite results are produced by injection of hypotonic solutions, such as distilled water.

Closure of the Wound and the Repair of Dural Defects. Fascial Transplantation.—The absolute necessity of careful closure of all layers of the wound is now well established as the only sure means of preventing hernia. That this is not sufficiently recognized can be learned by a visit to institutions caring for patients in the later stages following brain operations. One may find there some unfortunate sufferers with huge, unsightly, ofttimes fungating herniæ, and with resulting massive paralyses. Emphasis cannot be laid too often on the fact that decompressive operations should be placed only where there is adequate muscular and aponeurotic support for the bulging brain—the subtemporal and suboccipital regions.*

In osteoplastic flap operations suture of the dura is not infrequently impossible even after one or more of the enumerated methods for relieving increased pressure have been employed. Furthermore, suture of the dura is, of course, impossible when that membrane has been necessarily sacrificed in removing a tumor springing from it. Dural continuity is the best assurance against the development of a hernia. The chances are that a hernia will not develop with a well-fitting osteoplastic flap and careful closure of the layers of the scalp, even if no effort at repair of the dural defect is made. But bridging of the dural gap is the only certain method of preventing hernia. Various means have been employed to this end. The use of Cargile membrane for the purpose is illogical, I believe. There is no way of knowing whether it will remain spread over the cerebral cortex in the position in which it has been placed, leakage of cerebrospinal fluid cannot be prevented, the required support for the bulging brain is not given, and the fate of the foreign body is uncertain. Another method consists in splitting the dura into its two layers toward the operatively incised margin of that membrane. The flap is then turned over and sutured to the opposite cut margin of the dura. In greatly increased tension, a large enough flap for the purpose is ordinarily not to be obtained by splitting the dura; even should it succeed, a greatly weakened support for the whole of the underlying brain is the result. Unquestionably, the best method for the repair of the dural defect consists in suturing into the gap a sheet of fascia lata of the required shape and size. Experimentally and clinically I have shown that fascia is an ideal tissue for the replacement of visceral defects.[6] The studies of Kirschner[4] and of others have amply demonstrated the satisfactory results of transplanting fascia into dural gaps. The technic is simple. The required section of fascia lata having been removed, its deep surface is turned toward the brain and the fascia is fixed in place by four silk sutures attaching it to the cut edges of the dura. Interrupted silk sutures are

*The term "sellar decompression" for the relief of tension in hypophyseal neoplasms is used in a different sense. Generally increased intracranial tension may or may not be indirectly relieved by the operation; indeed, it is questionable if "decompression" is a correct term to apply to the transphenoidal operation for hypophyseal tumor.

then passed between these four points, approximating cut margin of dura to that of fascia. As shown elsewhere (page 155), I have transplanted large sheets of fascia into dural defects and they have healed in place and remained so without untoward effects.

One- and Two-stage Operations.—In the past two-stage operations were performed in the majority of cases. With improvement in technic and an appreciation of the danger of infection and leakage of subarachnoid fluid in two-stage operations the latter are now much more limited in their application. The following may be regarded as indications for operation in two stages: Bleeding so severe as to jeopardize the patient's life; badly taken anesthesia; patients in very poor general condition; or tension so great that the effects of a decompression must be awaited. The two-stage operation should become largely confined to some of the more difficult suboccipital craniectomies.

Treatment of the Tumor.—The great majority of brain tumors encountered at operation are more or less infiltrating gliomata. Chiefly for this reason the results of the surgery of cerebral neoplasms are so poor. A hopeful factor is that gliomata, although malignant growths, are prone to only local recurrence or metastases. There are, however, many difficulties involved in the problem of surgical removal of gliomata. A considerable proportion are inaccessible with the present surgical technic. Localization of the tumor is often made only late in the disease because focal symptoms are often absent until then. The limits of the neoplasm cannot usually be determined at operation. Incomplete removal of a glioma is certainly a less satisfactory operation than a simple palliative decompression. At the present time an unencapsulated superficially placed growth not involving the speech area or the motor cortex is the only infiltrating type of glioma in which radical excision can be considered. In other words, the glioma problem is as yet barely scratched. Means for determining the limits of these growths and better procedures for their removal will have to be developed before any real advance can be made in their operative treatment. Compared with the incidence of gliomata, other tumors are only occasional finds at operation. Investigation must, therefore, be concentrated upon the treatment of this all-important type of cerebral neoplasm.

Endotheliomata are the most favorable of the malignant tumors for operative removal. They, too, are apt to recur locally. Recurrence can best be obviated by sacrificing a sufficiently large area of dura when they spring from that membrane. As will be subsequently indicated, radical removal cannot be performed with the present technic of operation for tumors in the pontocerebellar recess, and further extension of the growth is unfortunately the rule.

Benign tumors are rarely met at operation. Cysts, with their predilection for the cerebellum, also belong to the small group in which brilliant results may be expected after excision. Aspiration of cysts is usually not sufficient; whenever feasible, the cyst wall should be removed in whole or in part.

Nevertheless, the proportion of tumors found at exploratory operations is as yet all too small, perhaps under 50 per cent., even after careful examinations by skilled neurologists. The work of Dandy* in the localization of cerebral tumors by ventriculography is an important and decisive step forward in the regional diagnosis of brain tumor. He believes that practically all brain tumors compromise the ventricular system either directly or indirectly, and that the resulting changes in the size, shape and position of one or both ventricles as shown by the ventriculogram will accurately disclose the situation of most tumors of either cerebral hemisphere. He demonstrates that a bilateral hydrocephalus can be readily shown by ventriculography and holds that a bilateral hydrocephalus, in cases of brain tumor, is almost certain evidence that the lesion lies in the posterior cranial fossa. If ventriculography did nothing more than to permit of this differentiation it would prove a great aid in many obscure cases, reducing the likelihood of useless or even dangerous operations in incorrect regions.

The decompressive operations, to which reference will be made subsequently, would be practised more intelligently; suboccipital decompression would be limited to lesions in the posterior fossa and subtemporal decompressions to lesions anterior to the tentorium. But Dandy's method offers more than the mere demonstration of the existence or absence of a hydrocephalus, for he has shown that the deformities of the ventricles due to tumor pressure can be clearly outlined and, as a result, tumors otherwise non-localizable in the cerebrum can be found at operation in the regions indicated by the ventriculogram.

In addition, ventriculography would appear to offer an *early* as well as an *accurate* localization of neoplasms and, accordingly, a much better outlook for radical cure by operation. Finally, the precision of the method would permit of exploratory craniotomy directly over the situation of the tumor and thus greatly simplify the operative technic.

The technic of ventriculography is described in the section on Hydrocephalus (p. 172). To introduce air into the ventricles of an adult a small cranial opening must, of course, be made. In some cases the ventricle on the side of the neoplasm is so reduced in size that it may be impossible to withdraw sufficient fluid to make air replacement a safe procedure. Under such circumstances it is best to make a ventricular puncture on the opposite side and inject air into this ventricle. Dandy holds that even a bilateral ventricular puncture is a small procedure as compared with a craniotomy or even a decompression, and that the results obtained in localization of the growth not infrequently make the puncture far more valuable than an exploratory craniotomy. The value of ventriculography and the apparent innocuousness of the method are clearly indicated in his paper in a variety of conditions. Of the 5 cases described in the report, the most striking is a patient who had been submitted to two cerebellar operations without disclosing the tumor. The neurologic manifestations were very confusing, but

* Paper on Localization or Elimination of Cerebral Tumors by Ventriculography published in Surgery, Gynecology, and Obstetrics, April, 1920.

the evidence appeared to indicate a lesion in the posterior fossa; 75 c.c. of cerebrospinal fluid were withdrawn from the right ventricle and replaced by an equal amount of air. Roentgenograms of both ventricles were taken, first in profile and then anteroposteriorly. The right ventricle was approximately normal (Fig. 150). The left ventricle ended abruptly near the middle of the body (Fig. 151), no air reaching the posterior or descending horns. The anteroposterior ventriculogram (Fig. 152) showed that the left ventricle was pushed over toward the right, the latter also being dislocated to the right. The results of ventriculography indicated clearly that the tumor was in the posterior part of the left cerebrum and not in the posterior fossa. At operation, with an exposure over the left occipital pole, an encapsulated tumor was found to arise from the wall of the ventricle exactly in the situation indicated in the ventriculogram. A complete and successful removal of the tumor was carried out.

The other cases reported by Dandy are also impressive illustrations of the value of ventriculography in the localization of neoplasms, but enough has been said to indicate what far-reaching results may be expected from the method, particularly after it shall have been perfected. At the present time one may well feel that with this addition to the diagnostic armamentarium the results of operation for brain tumor will be radically improved.

In a consideration of the advances made in the surgery of brain tumors in the past ten years two special types of operation come to the fore: the cranial approaches to the hypophysis and the suboccipital operation for tumors of the cerebellum or pontocerebellar recess. The former is detailed in Chapter XXXI. Before describing suboccipital craniotomy the fundamental operation of subtemporal decompression will be briefly discussed chiefly because some misunderstanding appears to have arisen as to its meaning and purpose.

Subtemporal decompression, first described by Cushing, remains the most beneficial operation in cranial surgery. It is, therefore, unfortunate that the meaning of decompression does not yet appear to be universally understood. It was pointed out (page 183) that, with the exception of sellar decompression, there are yet only two places in which decompression may properly be performed—the right subtemporal and the suboccipital regions. The reason is that in these areas alone can adequate muscular and fascial support be given to the bulging brain. Decompression by leaving the dura widely gaping can indeed be obtained in other regions, but with what unfortunate results has already been noted. Modifications of Cushing's operation have been described without clear demonstration of the advantages claimed for them. However, it must be conceded that unsightly herniæ occasionally develop after subtemporal decompression, and in that sense the operation sometimes fails. The reason is not far to seek. As already stated, the brain support depends on the sutured temporal muscle and fascia, and, very likely, more upon the latter than the former. When, as not infrequently happens, the temporal fascia is sutured under great ten-

sion, or is only incompletely approximated, inadequate support for the brain may be anticipated. Under such circumstances I have used the following plastic flap incisions of the fascia with satisfactory results. A **U**-shaped incision is made through the temporal fascia some distance from its cut margin, and the flap is turned back to be sutured to the opposite cut margin of the fascia. Support is thus obtained where it is most needed. The fascial rim left by the flap is sutured to the underlying muscle. In other instances I have detached and turned up a broad tongue-shaped flap from one lip of the divided temporal fascia, and then sutured it to the opposite lip; the free margins of the fascia are attached to the underlying muscle as in the previous technic.

Suboccipital Craniectomy for Tumors of the Cerebellum and Pontocerebellar Recess.—Until Cushing first pointed out the advantages of the bilateral over a unilateral craniectomy, in the approach to cerebellar and more particularly "recess" tumors, suboccipital operations were followed by a terrific mortality. His results have progressively improved so that the case mortality in his last series of tumors of the pontocerebellar recess was but 11.1 per cent.; the operative mortality was considerably lower since more than one operation was performed in a number of instances.[2] Furthermore, the results of operation have steadily improved, with better understanding of the method of removal of these tumors.

In a limited space it is impossible to discuss the nature of tumors of the pontocerebellar recess (they are chiefly tumors of the acoustic nerve), their diagnosis, or the development of the operation. As now practised, the operation may be sketched as follows: Controlling scalp bleeding with pressure by the fingers, a curved incision rising above the occipital protuberance is made from mastoid to mastoid. The scalp is stripped down to the superior curved lines and the added vertical incision of the "cross-bow" is placed exactly in the midline and carried down to the upper cervical vertebræ. Fascia and muscles are divided a short distance below the superior curved lines—it is important to leave enough attached to the occiput for subsequent suture—and the musculature is then stripped away from the bone. Full exposure of the occipital bone, the posterior rim of the foramen magnum, and the posterior margins of the mastoid processes must be obtained. The bone is trephined on both sides of the midline and these openings are enlarged with rongeurs. Greatest care to avoid injuring the sagittal sinus is taken in crossing the midline. The removal of bone must include all that has been exposed, taking in the posterior margin of the foramen. As landmarks the lateral sinuses are exposed. Bleeding from bone sinuses is checked with Horsley's bone-wax or, if necessary, with small wooden plugs; bleeding from branches of the marginal sinus is controlled by packing. If the dura is tense, a small incision is made through it near the foramen in order to tap the posterior cistern. This failing, and marked cerebellar protrusion being anticipated, a lateral ventricle is tapped through a trephine opening 3 or 4 cm. above the superior curved line and 2 cm. from the midline. The aspirating needle

is left in place. The dura can now be safely incised on either side of the midline, and, the sagittal cerebellar sinus being caught between clamps, the midline is crossed. Stellate incisions through the dura are then made to the margins of the bone defect. Exposure of the ponto-cerebellar recess is obtained by gentle retraction and elevation (a thin flexible retractor is made for this purpose) of the cerebellar lobe. A recess tumor is frequently capped by an encysted collection of fluid that should not be mistaken for a true cyst, and should, therefore, lead to

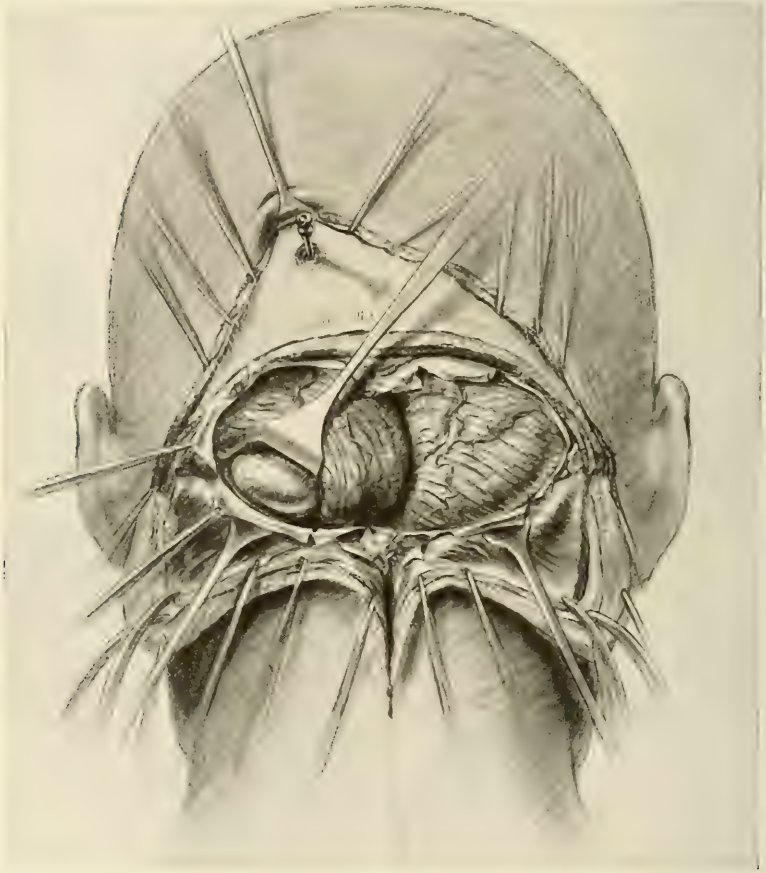

Fig. 157.—Showing Exposure of Encysted Fluid Within the Arachnoid Overlying a Tumor from a Sketch During Operation. (Cushing.)

further search for the tumor. Radical removal of tumors of the ponto-cerebellar recess is not feasible with the present technic because of the danger of hemorrhage without existing means for its control, and the likelihood of damaging cranial nerves and brain. Cushing therefore advocates incision through the capsule of the tumor and the subcapsular removal of more or less of the neoplasm with a blunt curet. The tumor may come away as a single mass or in many small fragments. All bleeding must be stopped before suture of the wound is begun.

Wound closure is obtained by careful approximation of the various layers, a procedure that must be most painstaking if there is to be no leakage of cerebrospinal fluid and if adequate support to the cerebellum is to be given.

Cushing's technic of approach to lesions of the posterior fossa represents a great advance. His method of removal of recess tumors ap-

FIG. 158.—SHOWING, NEAR THE FORAMINAL REGION, THE PRIMARY SMALL OPENINGS IN THE DURA AND SUBSEQUENT PUNCTURE OF THE LATERAL VENTRICLE IF FAILURE TO SECURE FLUID AND EXTREME TENSIONS DEMAND. (Cushing.)

pears to be the best available at the present time. However, better methods must be developed than one which is almost certain to be followed by continuation of growth of the tumor.

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CHAPTER XXXV

THE SURGERY OF THE FIFTH (TRIGEMINAL) NERVE*

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If the experience of an individual surgeon is a criterion, major or epileptiform type of trigeminal neuralgia is becoming more prevalent, and, what is perhaps more interesting, one sees it now more often in people under forty years of age. A decade ago when a patient under forty years of age was said to have the major form of trigeminal neuralgia, one was skeptical as to the accuracy of the diagnosis and had grave suspicions of a pure neurosis. In the ten years that have elapsed since the original chapter in Volume V of Keen's Surgery was prepared the treatment of trigeminal neuralgia has been reduced to a comparatively simple problem. The treatment may be said to be standardized; for the palliative treatment alcoholic injections, for permanent relief division of the sensory root. All other methods have been replaced by one or the other of these. Which of the two methods is applicable in a particular instance depends upon many circumstances. There are exceptional instances when the age or condition of the patient forbid a major operation, and an exceptional contraindication is defective vision on the opposite side. Even though the likelihood of trophic keratitis is remote, it must be given consideration when the patient is dependent upon vision of the eye on the affected side. These may be said to be the positive contraindications to the major operation. The others are relative, that is, they relate to the wish or whim of the patient. Given a case of short duration, the patient, in full knowledge of the transitory effect of an alcoholic injection and the enduring effect of a radical operation will, with but rare exceptions, choose the injections. The injection given, he leaves, pitifully grateful for the immediate relief, and encourages himself to believe that this is the end of his suffering. Before the year ends the pain returns. He fights it out for a while and then returns submissively for another injection. Three or four years pass, with as many injections, and either because the injections are becoming less effective or—and this is the more potent influence—because his courage is failing, the patient refuses to have another injection, and pleads for the major operation as the only possible means of permanent relief.

When, however, the patient has been a victim of the disease for many years he is, as a rule, unwilling to consider any treatment of transitory effect and will consider only an operation which assures him

* Supplementary to Chapter LXXIX, Vol. V, p. 964.

of complete and permanent relief. Hence to deal effectively with trigeminal neuralgia one must be familiar with the technic of but two procedures—alcoholic injections and section of the sensory root of the gasserian ganglion.

The scope of this chapter limits the discussion to the intracranial surgery of the trigeminal nerve, and this, in turn, resolves itself into a description of the operation on the sensory root. With the exception of Hutchinson, neurologic surgeons have abandoned either the complete or partial excision of the ganglion, and today we find universally accepted the operation on the sensory root. The operation was proposed by Spiller in 1901, later paraphrased by von Gehuchten as "the physiologic extirpation of the ganglion," and by Morestin as the "isolation of the gasserian ganglion." According to Jaboulay, this operation is

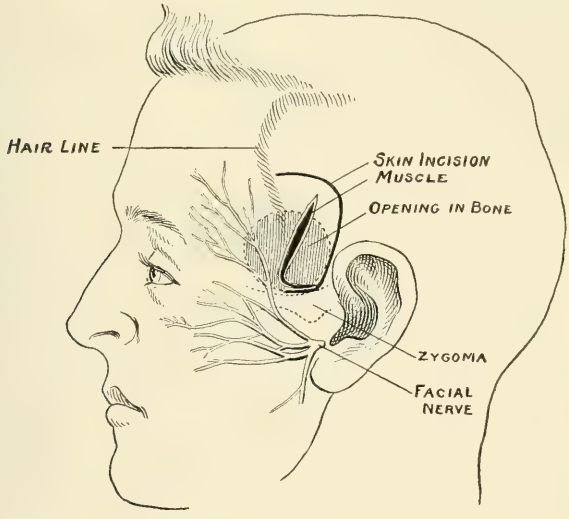

FIG. 159.—RELATION OF INCISION TO THE UPPER BRANCH OF THE FACIAL NERVE.
It is most important that the upper branch of the facial nerve be conserved; otherwise disastrous results might follow from the inability of the patient to close the eyelids. The old-fashioned horseshoe incision assured no protection to this branch.

"equally efficient, and much less dangerous than gasserectomy, more easy of accomplishment, and therefore to be preferred in all cases." The operation now has the endorsement of the leading surgeons, including Jaboulay and others (quoting Rasumowsky, Arch. klin. Chir., Bd. 88, Hft. 4). Modified in many ways the various steps will be described again in some detail.

The operation is performed under ether anesthesia in the sitting posture. This is the position of greatest convenience to the operator. The incision is designed to avoid the upper branch of the facial nerve, to be concealed within the hair line and to give direct access to the foramen ovale. The skin-flap is reflected forward, the temporal muscle and aponeurosis backward, and both secured in these respective positions by suturing the flaps to the wound draperies (Figs. 159, 160).

The temporal bone thus exposed, an opening is made with a Hudson drill and enlarged to the diameter of 2.5 cm. By keeping the opening

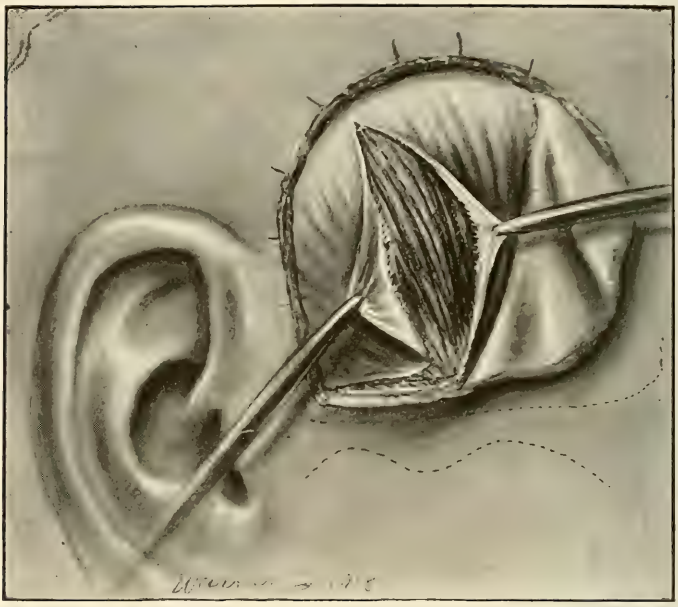

FIG. 160.—METHOD OF APPROACH TO THE GANGLION; CUTANEOUS FLAP REFLECTED FORWARD. The line of incision in the temporal fascia and muscle is projected so that this musculo-aponeurotic flap may be reflected backward.

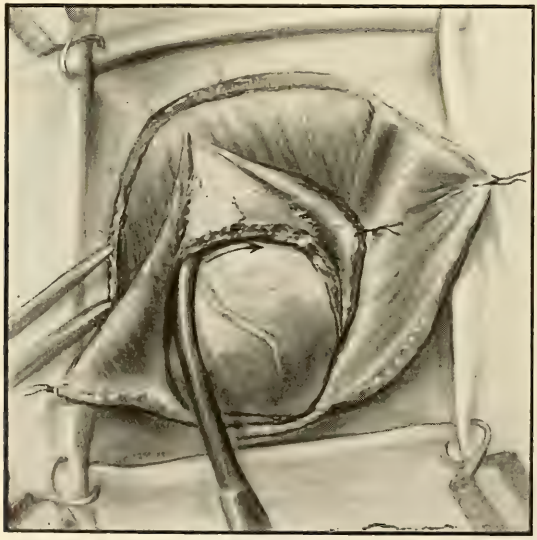

FIG. 161.—SEPARATION OF THE DURA AS WIDELY AS POSSIBLE FROM THE MARGINS OF THE BONY OPENING.

within these dimensions the upper margin of the bony opening prevents any harmful pressure by the brain spatula upon the temporosphenoidal

lobe (Fig. 161). The dura is now separated from the bone above and to either side of the bony opening to the limits of the middle fossa. One finds the dura more intimately attached to the bone along a line corresponding to the level of the base of the skull, and unless this be recognized, the dural separator will readily penetrate the dura, and its separation beyond this point is thus rendered more difficult. As the dura is separated from the base of the skull in the direction of the foramen ovale, the temporosphenoidal lobe is gently elevated, and one follows the groove for the middle meningeal artery until it leads to the point where the artery can be seen emerging from the foramen spinosum (Fig. 162).

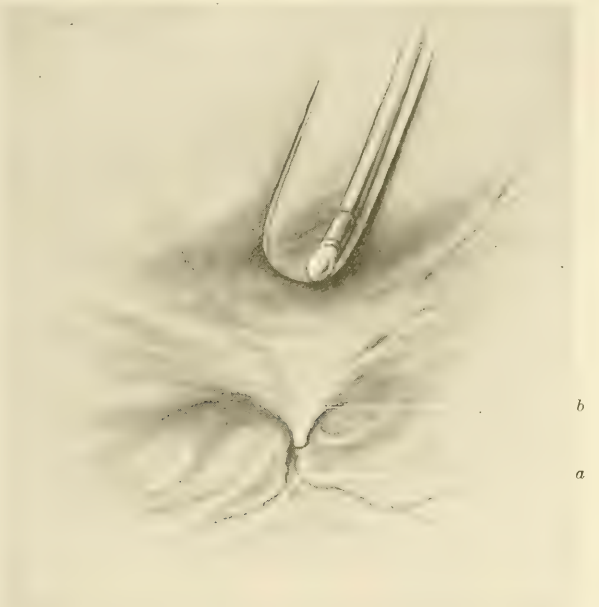

FIG. 162.—IN THIS ILLUSTRATION ARE SEEN (*a*) THE GROOVE OF THE MIDDLE MENINGEAL ARTERY AND ITS ANTERIOR AND POSTERIOR BRANCHES ON THE FLOOR OF THE MIDDLE FOSSA; (*b*) THE ARTERY AND ITS BRANCHES COURSING ALONG THE DURA AND LEADING TO THE FORAMEN SPINOSUM. Immediately to the right of the foramen spinosum can be seen the outline of the foramen ovale. The field of operation is illuminated by the author's special retractor mounted with an incandescent lamp.

The next step is the control of hemorrhage from the middle meningeal artery. This is readily and most expeditiously accomplished by plugging the foramen with Horsley's wax or a pledget of cotton. It is unnecessary and time consuming to ligate the vessel. After the foramen is plugged the artery is cut with a scalpel and the dura separated from the skull until one readily sees the mandibular division entering the foramen ovale (Fig. 163). This landmark is the guide to the gasserian ganglion, and the next step is one of the most important. The superior surface of the posterior half of the ganglion is to be exposed, and one must look for the line of cleavage between the dura and the dura propria or sheath of the ganglion. With proper illumination this line of cleavage can be seen, and with a blunt dissector or, if need be, a scalpel the

separation of these structures is accomplished until the posterior half of the superior surface of the ganglion is in full view. To expose the sensory root of the ganglion, the next to the last step of the operation, an incision is made in the ganglionic sheath parallel with the fibers of the sensory root (Fig. 164). The latter is readily recognized by its loose structure, in striking contrast to the dense tissue of the ganglion itself. The root must be completely exposed to view up to the point it passes over the apex of the petrous bone where one can see a sharply defined opening in the dura. If not on one's guard, some of the fibers of the root may remain adherent to the overlying dura, be concealed by the brain

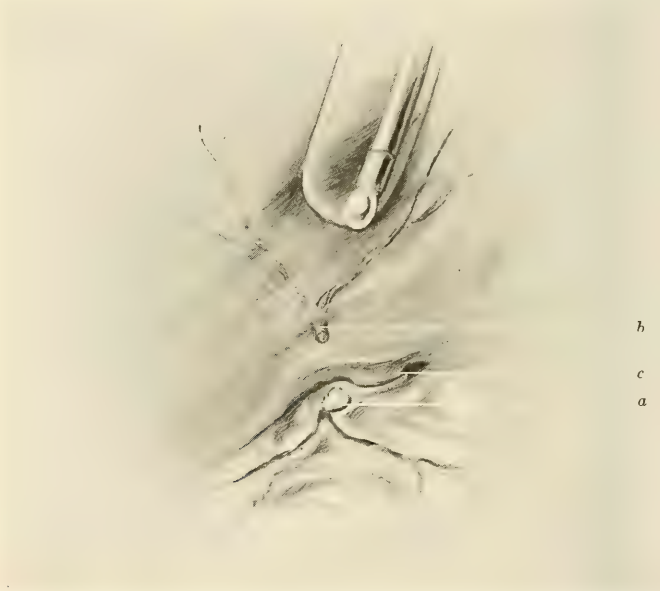

FIG. 163.—IN THIS ILLUSTRATION CAN BE SEEN (*a*) THE FORAMEN SPINOSUM WHICH HAS BEEN PLUGGED WITH COTTON AND (*b*) THE STUMP OF THE MAIN TRUNK OF THE MIDDLE MENINGEAL ARTERY AFTER ITS DIVISION, AND (*c*) A WHITE LINE JUST ABOVE THE MARGINS OF THE FORAMEN OVALE, WHICH REPRESENTS THE POINT OF CLEAVAGE BETWEEN THE DURA AND THE DURA PROPRIA OF THE GANGLION.

The identification of this line is essential in carrying out the next step of the operation, the exposure of the superior surface of the ganglion. If this line of cleavage is followed, the superior surface of the ganglion may be readily exposed without hemorrhage. If the incision should be superficial to the line of cleavage, the subarachnoid space will be opened. If the incision is made through the dura propria, the exposure of the ganglion itself on the plane between the dura propria and the ganglion will be attended with considerable oozing.

sptaula, and be overlooked when the root is sectioned. If the root be incompletely divided, the patient will be only partially relieved.

The root is now isolated on a special blunt hook and divided with a sharp scalpel (Figs. 165, 166). There is no necessity for resection. There may be some advantages in section of the root over its avulsion. This is the final stage of the operation and there remains only the control of bleeding and the closure of the wound. The wound is closed with tier sutures.

Recently I have introduced a refinement in the technic of the operation that is of considerable moment. Hitherto the motor root had, in

FIG. 164.—THE SUPERIOR SURFACE OF THE POSTERIOR THIRD OF THE GANGLION, EXTENDING FROM THE FORAMEN OVALE BACK TO THE APEX OF THE PETROUS BONE HAS BEEN EXPOSED.

The reflection of the dura can be distinctly seen, and on the surface of the ganglion there is a crucial incision through the dura propria which is the step immediately preceding the exposure of the root.

FIG. 165.—THE DURA PROPRIA HAS BEEN REFLECTED ON EITHER SIDE OF THE INCISION PREVIOUSLY MADE, AND THE ROOT WITH ITS LOOSE TEXTURE HAS BEEN EXPOSED AND ELEVATED UPON A SPECIAL HOOK PRELIMINARY TO ITS SECTION.

most cases, been divided with the sensory root. No deliberate attempt had been made to isolate and leave it intact. This I have found possible by the use of an electrode. The sensory root is elevated carefully and beneath it may be seen the motor root. In order to assure oneself that the fasciculus is the motor root and not a portion of the sensory root, the fasciculus is electrically stimulated and there follows a contraction of the temporal muscle readily seen at the margins of the wound (Fig. 167). The significance of this refinement in the technic is apparent. By saving the motor root one conserves the function of the muscles it supplies, the temporal, masseter, and pterygoids. This serves a twofold purpose, the first cosmetic in effect, the second of assistance in mastication. Atrophy of the temporal muscle inevitably followed

FIG. 166.—USING A SCALPEL WITH A SMALL BLADE AND A LONG HANDLE THE SENSORY ROOT IS SECTIONED.
After the stump is reflected the fasciculi can be seen.

section of the motor root, and as a result there appeared in course of time a marked depression above the zygoma in the temporal fossa. This was very noticeable, and to avoid the disfigurement some operators routinely resected the zygoma. Now the symmetry of the face is preserved. Second, the conservation of the function of the masseter and pterygoids preserves the normal movements of the jaw and avoids disturbance in mastication, which in some instances was a source of annoyance to the patient.

Hemorrhage is the traditional bugaboo of operations upon the gasserian ganglion. There was some justification for this when the operation for trigeminal neuralgia involved the removal of the ganglion itself because a troublesome and uncontrollable hemorrhage inevitably ac-

companied the elevation of the ganglion from its base, whence its source of blood-supply. But, as in section of the sensory root, the ganglion is not lifted from its bed, there need be no apprehension as to hemorrhage, other than the moderate oozing which may sometimes try the patience of the operator if he is not familiar with methods of control. One can always control oozing with cotton tampons judiciously placed. Apart from hemorrhage from the middle meningeal artery, so easily prevented by preliminary plugging of the foramen spinosum, the only other source of free bleeding arises when the dura is separated from the

FIG. 167.—THE FINAL STAGE IN THE OPERATION CONSISTS IN THE IDENTIFICATION OF THE MOTOR ROOT. This is accomplished with a fine electrode. The motor root lies immediately posterior to the sensory root and is not as sharply defined as appears in the illustration. In order to assure oneself that it is not a fasciculus of the sensory root it should be stimulated with an electrode, which causes contraction in the muscles supplied by the motor root, including the pterygoids, masseters, and temporal. The latter is in the field of operation so that its contractions can be readily seen. Note also in this illustration the outline of the opening in the dura through which the sensory root passes from the middle to the posterior fossa. As this opening is fully exposed at the operation one can readily determine whether all of the fasciculi of the sensory root have been divided. If not, it is possible that the fasciculi of the inner portion of the root may be overlooked.

ganglion at the point at which the maxillary division is given off. Here there is a dural vein which, if ruptured by the dissection, bleeds freely. Fortunately, as a rule, it is not necessary to uncover the ganglion as far forward as this point, and hemorrhage from this source is therefore avoidable in most instances. After the root is divided, and the temporosphenoidal lobe allowed to drop to the base of the skull, oozing from all sources usually will cease spontaneously, but should there be continued oozing, as from the point above mentioned, it is readily controlled by the application of a small muscle graft readily procured from the temporal muscle.

Results.—Assuming that the sensory root has been completely divided, the results are permanent. There can be no regeneration of the nerve tissue central to the ganglion, and this general rule applies as much to the sensory root of the gasserian ganglion as to any other part of the central nervous system. In only one instance have I had occasion to operate a second time because of recurrence, and in this instance I found a few fibers of the root had been overlooked.

Complications and Sequelæ.—A decade or more ago in discussions upon the complications of gasserectomy one frequently read of injuries to adjacent structures, as the third, fourth, and sixth nerves, and occasionally to the cavernous sinus; and there were reports of aphasia and partial hemiplegia from undue pressure upon the cerebral cortex. Since section of the sensory root has supplanted gasserectomy one no longer hears of these complications.

Occasionally a writer will report a partial and usually transitory paralysis of the facial nerve, but if the incision is intelligently planned with respect to the course of the facial nerve this complication should never occur.

Trophic keratitis is the only complication that cannot be avoided in every instance. In a small percentage of cases signs of keratitis will appear within forty-eight to seventy-two hours after the operation, but by appropriate treatment, closure of the lids, instillation of atropin and irrigation with boric acid solution, the threatening signs will disappear. In two instances in my own experience it has been necessary to keep the lids closed at their midpoint, since, whenever the lids were opened, the signs of keratitis recurred. Although the lids are in contact at their midpoint the palpebral fissure on either side is wide enough to allow the patient to see. This method of dealing with trophic keratitis is an absolute guarantee against the development of any destructive lesion.

After the radical operation some patients will complain of a variety of disorders of sensation difficult of understanding. When objectively there is no complete anesthesia for both touch and pain in the entire trigeminal distribution, one wonders why there should be any subjective sensory phenomena, and yet occasionally a patient will experience paresthesias, sometimes described as creepy sensations, sometimes as drawing sensations. Again, a sensation will be experienced traveling the same route as did the pain before the operation. Differing from the above and yet equally difficult of explanation is a sense of fulness in the ear. The patient states that he cannot hear as well on the affected side as on the unaffected side, but a careful examination will fail to detect any difference between the two sides. These and other paresthesias have been called to my attention and have excited my curiosity as to their origin. As a rule in the course of a few months they disappear.

Mortality.—The idea still prevails among physicians that the death-rate after the radical operation is high. The patient has been told that there is great risk in the operation, that the effects of the operation are disfiguring, that a facial paralysis and loss of the eye are

not uncommon complications. Allusion to operation in a popular text-book as "bloody, difficult, and dangerous" is descriptive of the impression still prevalent in the profession. In 1909 the mortality, based upon a series of 230 cases from the clinics of Horsley, Lexer, Dollinger, Cushing, and myself, was 3.7 per cent. In my chapter in Volume V I stated that in all probability during the next ten years the mortality would be still further lowered. This forecast has come true. In a series of 82 consecutive operations in my clinic at the University Hospital from 1912 to 1918 there were no deaths; in a total number of 144 consecutive operations from 1912 to the present there has been one death in a patient, who ten days after operation, when ready to be discharged, developed apoplexy. Thus the mortality has been reduced to 0.6 per cent., and when one takes into consideration that the operation is performed upon patients of advanced years and often debilitated, the record compares more than favorably with major operations in other regions.

Hutchinson's Operation.—As aforesaid, section of the sensory root is the accepted surgical procedure among neurologic surgeons with one exception. Hutchinson (Lancet, July 6, 1918) still advocates the operation he has practised for a number of years, namely, partial excision of the ganglion, sparing its inner portion from which is given off the ophthalmic trunk. In a series of 60 operations the mortality was 1.6 per cent. As an evidence of the greater difficulty of the operation there developed as complications 4 cases of hemiparesis. This experience should make one question the propriety of continuing the practice of this method in the absence of similar complications by the alternate method. In favor of the operation is the greater assurance against trophic keratitis when the ophthalmic division is left intact. Among other complications Hutchinson records facial paralysis, and this he attributed to the detachment of the dura mater from the upper surface of the petrous bone, permitting the entrance of blood into the small openings leading to the aquæductus fallopii.

CHAPTER XXXVI

TUMORS OF THE GASSERIAN GANGLION*

By Charles H. Frazier, M. D.,
Philadelphia

Up to the present time there are on record 43 cases of tumors of the ganglion, but in many instances these so-called "tumors of the gasserian ganglion" are, in reality, only tumors of the middle or posterior fossa with coincidental involvement of the ganglion, and not infrequently of other contiguous nerves. Of the total number, only 14 were exposed on the operating table, the remainder at autopsy.

The great majority of these 43 recorded cases have been either sarcoma or endothelioma, as will be seen in the accompanying table:

Sarcoma	15
Endothelioma	10
Carcinoma	3
Glioma	3
Gumma	2
Fibroma	1
Neurocyst	1
Aneurysm	1
No diagnosis	7
	43

According to Hellsten (Deutsch. Ztschr. f. Nervenheilk, 1914, lii, 290) the ganglion possesses a peculiar resistance to the invasion of tumors. Practically all take their origin not from the gasserian ganglion, but from the dura or some other structure of the middle fossa, and involve the ganglion only coincidently. While at first they may be limited to the region of the ganglion, they expand often in the form of a flat growth along the floor of the middle fossa, occasionally invading the orbit, the sella turcica, or even the posterior fossa.

The symptomatology suggests at first tic douloureux, but the detection of hypesthesia and hypalgesia and the development of trophic keratitis should at least arouse one's suspicion, and when involvement of adjacent structures becomes evident the diagnosis can be made with reasonable certainty. By this time the tumor exhibits symptoms common to tumors of the base of the middle and sometimes the posterior fossa. Hofmeister and Meyer (Deutsch. Ztschr. f. Nervenheilk., vol. xxx, p. 206) produced severe pain on percussion in the right temporal region, and a deep tone, which was limited to a spot the size of a mark, immediately over and in front of the right auditory meatus.

* Supplementary to Chapter LXXIX, Vol. V, p. 964.

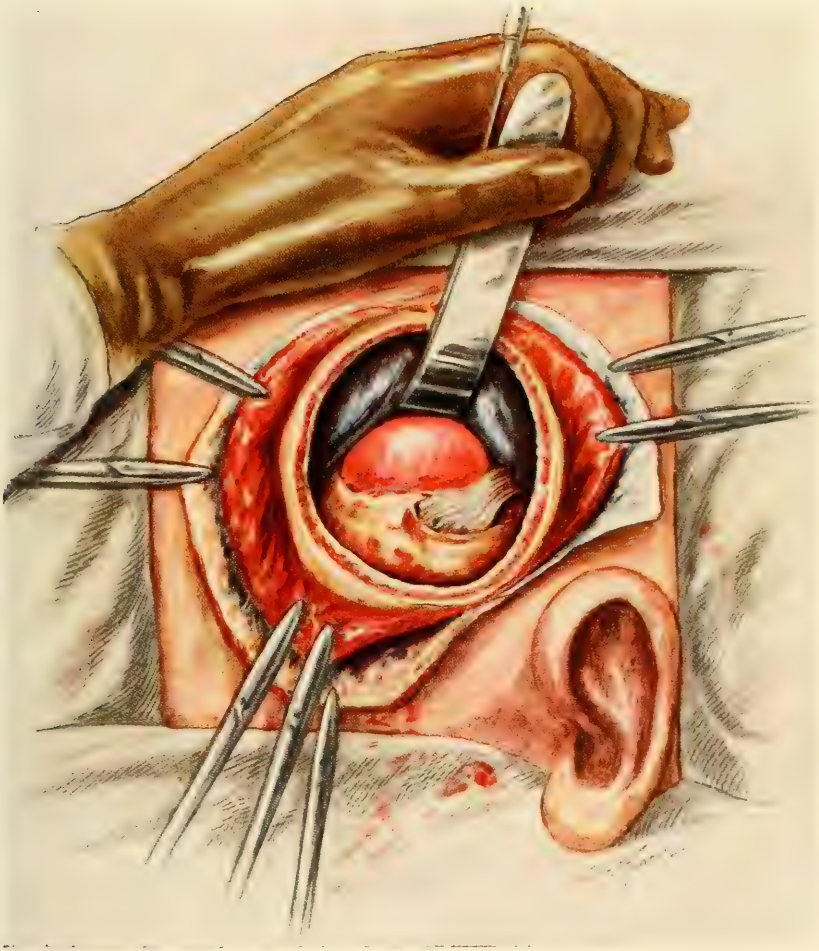

Fig. 168.—Drawing Showing Relation of the Tissues of the Gasserian Ganglion to the Third Division and the Superior Surface of the Ganglion, Drawn in the Course of the Operation. (Frazier.)

The patient, aged fifty-three years, had been suffering from pain in the distribution of the second division of the trigeminal nerve, at first jumpy in character, later becoming more intense and constant. Later numbness developed in the upper lip. The case was at first thought to be one of tic douloureux. Two successive alcoholic injections failing to give relief, an exploratory operation was performed, at which the tumor was revealed.

STATISTICAL TABLE FROM AN ANALYSIS OF 29 CASES

Age of patient:	
20 to 30 years	7
30 to 40 years	6
40 to 50 years	7
50 to 60 years	1
70 to 80 years	1
Left or right side:	
Left side	15
Right side	6
Primary, etc.:	
Primary	9
Secondary	9
Doubtful	3

REGIONAL SYMPTOMS

1. N. trigeminus:	
Pain in trigeminal distribution	8
Hyperalgesia	1
Pain and anesthesia	4
Parasthesia	1
Anesthesia	3
Anesthesia confined to left cornea and left half of tongue	1
Loss of corneal reflex	4
2. N. oculomotor:	
Ptosis: Unilateral	3
Bilateral	2
3. N. abducens:	
Diplopia	3

NEIGHBORHOOD SYMPTOMS

Deafness	1
Tinnitus	1
Hemiplegia	3
Paraplegia	3

SYMPTOMS OF INCREASED INTRACRANIAL TENSION

Headache	4
Dizziness	2
Vomiting	1
Ataxia	2

It is not difficult to understand that occasionally tumors involving the gasserian ganglion are confused with tumors of the cerebellopontile angle, or, indeed, with certain inflammatory processes involving the base of the brain. The gasserian ganglion, situated as it is in the middle fossa on the anterior surface of the petrous portion of the temporal bone and protected by its dural envelope, is seldom invaded by tumors arising in the cerebellopontile angle. Nevertheless the root of the trigeminal nerve, as it makes its exit from the pons, may be so involved as to cause both subjective and objective sensory disturbances which can scarcely be differentiated from those caused by implication of the ganglion itself. Although a tumor of the gasserian ganglion may occasionally implicate the eighth nerve, deafness seldom develops until very late in the course of the disease, and only after the severe subjective and objective disturbances of the trigeminal nerve have persisted for

some time. On the other hand, eighth nerve involvement is not unusual in "recess" tumors, and in "acoustic" tumors the nerve is, of course, uniformly involved. Of other manifestations of cerebellopontile tumors ataxia has also been observed in tumors of the gasserian ganglion, but only in exceptional cases.

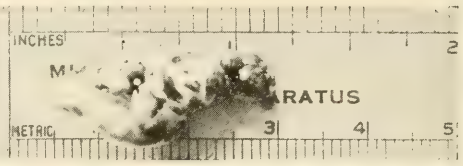

Fig. 169.—Photograph of Tumor as Shown in Fig. 168 After Removal. (Frazier.)

The treatment of tumors of the gasserian ganglion in the majority of cases has been ineffective. Since the first operation by Krogius (Revue de Chirurgie, vol. xvi, 434) there have been recorded only 14 operations.

CHRONOLOGIC TABLE OF THE RECORDED OPERATIONS UPON "TUMORS OF THE GASSERIAN GANGLION"

Date.	Recorder.	Operator.	No.
1895	Krogius	Krogius	1
1900	Keen	Keen	1
1906	Hofmeister	Hofmeister	1
1906	Spiller	Frazier	2
1907	Marchand	Marchand	1
1908	Giani	Durante	1
1911	Hartig	Krause	3
1913	B. Sachs	Berg	1
1916	E. Sachs	E. Sachs	1
1918	Frazier	Frazier	1
1918	Percy	Percy	1
			14

Of the 14 operations, the tumors were inoperable in 10 and the mortality was high. There were, however, 4 distinctly operable cases (Berg, Sachs, Percy, Frazier), in each of which the tumor was removed in its entirety. Even though a radical operation is not possible, one should consider the temporary relief that will follow the section of the sensory root and a subtemporal decompression. Patients with ganglion tumors present a most pitiable state. Not only is the pain quite as dreadful as that of tic douloureux, but it is more constant, so that any treatment which promises a measure of relief is welcome. One should bear in mind, however, the possible persistence of pain even after the ganglion has been removed, a phenomenon attributed to involvement of the sensory root.

CHAPTER XXXVII

WAR WOUNDS OF THE FACE AND JAWS

By Richard H. Harte, M. D., and Walter Estell Lee, M. D.,
Philadelphia

The surgical treatment of the injuries of the face and jaws during the recent European War (1914–18), like that of the surgery of other parts of the body, was a gradual evolution. Like all the surgery of the war, it can be divided into two periods—one before the development of adequate methods for the prevention and control of wound infection, and one after that control had been secured.

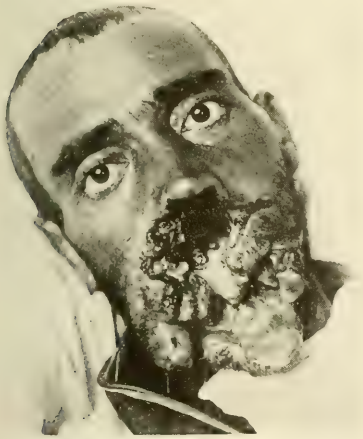

Fig. 170.—Hand Grenade Wound of Face of a French Soldier Admitted to the American Ambulance, 1915.

Fig. 171.—First Plastic Operation After a Lapse of Six Months.

In the early period the efforts of the surgeons were chiefly concerned with devising fixation apparatus and corrective appliances for overcoming deformities that were in a large part the result of improper and inadequate early treatment. Partly because of the lack of organization, but essentially because of the lack of knowledge of the possibilities of primary, delayed primary, and secondary closure, the wounds of the face and jaw were treated expectantly; and when they finally reached a base hospital infection was established, scar tissue and cicatricial bands had formed, while pseudo-arthroses and malunion were frequently present.

The restoration and correction of these unsatisfactory results required long and laborious treatment, and even then the final condition

was usually far from satisfactory. Figure 170 is a photograph of a French soldier with a hand grenade wound of the face who was admitted

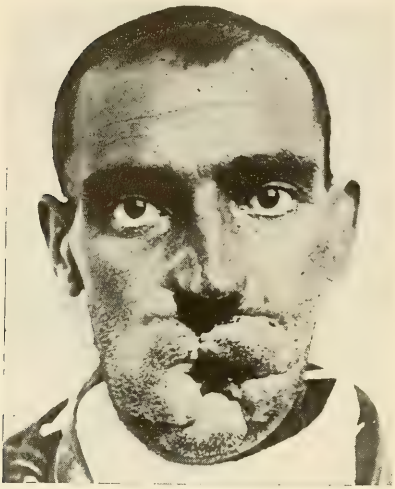

FIG. 172.—RESULT OF FIRST PLASTIC OPERATION.

FIG. 173.—RESULT OF SECOND PLASTIC OPERATION.

to the American Ambulance at Neuilly sur Seine in the early part of 1915.

During this early period all reparative surgery was deferred until the wound infection had become quiescent, which meant until the

FIG. 174.—RESULT AFTER THIRD PLASTIC OPERATION.

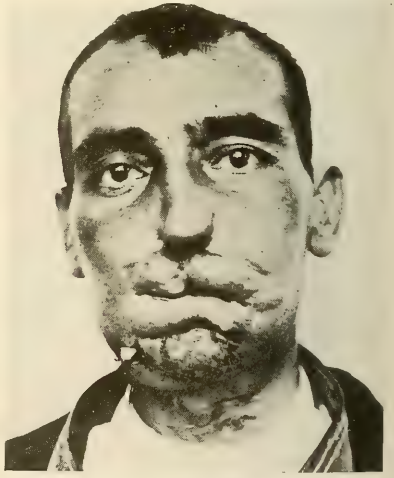

FIG. 175.—RESULT AFTER THIRD PLASTIC OPERATION.

tissues, by prolonged suppuration and sloughing, cast off the devitalized areas and developed a local resistance to the bacteria. Six months

elapsed before the first plastic operation was performed. Figures 171–175 show the progressive attempts which followed, and Fig. 176 shows the condition when he was discharged from the hospital more than a year after his admission.

The scar tissue formed during this period was, of course, the insuperable handicap to plastic surgery in this case, but the photograph cannot show the extensive scar tissue in the floor of the mouth which absolutely fixed the tongue, making it necessary for him to be fed liquid food through a tube, and caused his speech to be almost unintelligible.

This case is exhibited not as an exceptional one, but as representing a very large proportion of the faciomaxillary group in the early years of the war.

Fig. 176.—Result Upon Discharge from American Ambulance Twelve Months After Admission.

Figure 177 shows a less severe type of wound in which the soft tissues of the mouth and cheek were involved, but the scar tissue resulting from delayed closure of the wound produced the deformity shown in Fig. 178. An extensive excision of this scar tissue was necessary before the plastic restoration shown in Figs. 179 and 180 was possible.

In contrast, Fig. 181 is a photograph of a French soldier admitted to the same hospital in the latter part of 1916. The extensive wound of the soft tissues and fracture of the inferior maxilla was produced by a fragment of shell. Though forty-eight hours had elapsed after the receipt of the wound and gas organisms were found in the tissues, the jaw was splinted, and after the wound had been mechanically cleaned with soap, water, and Dakin's solution, the wound edges were closed.

Figure 182 shows the wound healed on the seventh day, when the sutures were removed. This was one of the first attempts at the

FIG. 177.—HAND GRENADE WOUND OF FACE, ADMITTED TO AMERICAN AMBULANCE, 1915.

FIG. 178.—SCAR RESULTING FROM HEALING OF THE WOUND BY GRANULATIONS.

FIG. 179.—SIX MONTHS AFTER RECEIPT OF WOUND, EXCISION OF SCAR AND PLASTIC OPERATION.

FIG. 180.—END-RESULT.

American Ambulance of early closure of face wounds, and was the work of Major Charles A. Powers, of Denver, Colorado. Figures 183

and 184 illustrate another successful early closure (on the third day) of a wound of the mouth and lips.

FIG. 181.—GRENADE WOUND OF FACE, ADMITTED TO AMERICAN AMBULANCE, 1916. SEVENTY-TWO HOURS AFTER INJURY DÉBRIDEMENT AND PRIMARY SUTURE BY MAJOR POWERS.,

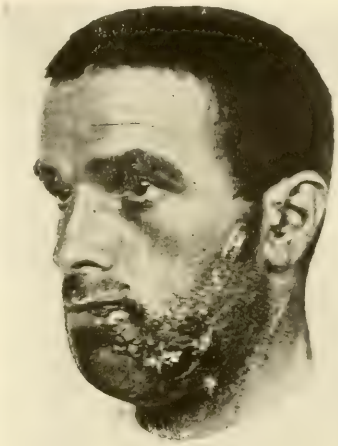

FIG. 182.—END-RESULT UPON REMOVAL OF SUTURES.

Industrial surgeons had demonstrated the unusual resistance of facial tissues to traumatic wound infection long before this war, but

FIG. 183.—GRENADE WOUND OF LIPS ADMITTED TO AMERICAN AMBULANCE, 1916. DÉBRIDEMENT AND PRIMARY SUTURE ON THIRD DAY BY MAJOR POWERS.

FIG. 184.—END-RESULT.

the disastrous results which followed the attempts at early closure of the gunshot wounds in other parts of the body discouraged military surgeons in making a distinction in face wounds. In the latter part of

1916 the experimental and clinical work of Dakin, Carrel, LeMaistre, and Duval conclusively demonstrated that the unusual factors in war wounds were the missiles, the extensive masses of devitalized tissues, the constant soil contamination, and delayed surgical treatment, and that if these unusual factors were removed war wounds could be expected to heal in the same manner as civil wounds. The prompt surgical removal of the missile and the contaminated and devitalized tissues, which they advocated, usually permitted of a closure of the wounds, and particularly those of the face, before the formation of the scar tissue.

The contrast in the faciomaxillary problems before and after the practice of adequate measures for the prevention and control of wound infection and the closure of the wounds before the development of scar tissue is so marked there is no doubt that these principles should be applied to the civil surgery of faciomaxillary wounds.

Fig. 185.—Dental Operating Room, American Ambulance, Neuilly Sur Seine.

Though nearly two years elapsed before the general acceptance and application of the principles of prevention and treatment of wound infection in faciomaxillary wounds, the necessity for the *fixation* of the bony fragments in these wounds was recognized from the first. That it was not generally practised was because of the lack of medical organization and a supply of properly trained dental surgeons. The first organized effort to meet the special difficulties encountered in the splinting of bones in jaw wounds was made at the American Ambulance at Neuilly sur Seine by Blake, Hutchinson, Harte, Davenport, and Hayes. Similar organizations were developed in all of the Allied Armies as the war progressed. The detail of this phase of the work is thoroughly described by Dr. Darcissac (Chapter XXXVIII), and in this section these special forms of dental splints will only be referred to in a general way.

The plan adopted for the care of faciomaxillary wounds by the Medical Corps of the A. E. F. is practically a summary of the experiences of the military surgeons of the Allied Armies during the three years preceding the coming of the American Army to France, and it is a recapitulation of the above foreword.

To each hospital was attached a dentist who was to be called upon to assist the general surgeon in the treatment of fractures of the jaws and plastic reconstruction of the soft tissues. The actual surgery of the soft parts and the general supervision of the cases devolved upon the general surgeon.

For the guidance of the surgeons and dentists in the care of maxillofacial wounds the Chief Surgeon of the A. E. F. issued the following instructions:

1. All the maxillofacial wounds shall undergo a thorough mechanical cleansing at the earliest possible opportunity.
2. There shall be no débridement of face injuries.
3. No bone fragments shall be removed that have any soft tissue attachment.
4. Immediate steps shall be taken to arrest hemorrhage and prevent secondary hemorrhage.
5. There shall be immediate fixation of all fractures.
6. Adequate inferior drainage shall be established in all fracture cases.
7. As much primary suture of face cases shall be done as is consistent with good surgical principles.
8. All cases shall be evacuated to the base hospitals as quickly as possible.

In several respects these instructions conflicted with those issued for the treatment of war wounds in general. The thorough débridement which was advised for all gunshot injuries, because of the danger of infection developing in the devitalized tissues, particularly that of the gas bacillus, was not advised in face wounds for two reasons: First, thorough débridement of all face injuries would have meant the sacrifice of an immense amount of facial tissues which never could have been adequately replaced; second, it was shown clinically that there was practically no danger of gas infection developing in facial tissues. An illustration is the case of the French soldier who was admitted to the service of Dr. Charles A. Powers in the American Ambulance at Neuilly (see page 207, Figs. 181 and 182). The accepted explanation of the unusual resistance of facial tissues to gas infection is their abundant blood-supply.

THE TREATMENT OF WOUNDS OF THE FACE

Contusions.—The loose subcutaneous tissues of the face permit of rapid and extensive extravasation of blood, and the disfiguring swelling and discoloration are well known. Pressure and cold compresses for a few hours after the injury tend to arrest the subcutaneous bleeding. Pressure probably is of little value after two hours. Cold applications

should be discontinued after eight or ten hours, when the cold is likely to interfere with the process of absorption.

Incised and Lacerated Wounds.—The necessity for the earliest possible surgical treatment of incised and lacerated wounds of the face is just as urgent as in other parts of the body. The making of a formal aseptic operation, under general anesthesia if necessary, of every primary dressing of faciomaxillary wounds should be an invariable rule. In Gibbon's chapter upon Surgical Technic mechanical wound cleansing and primary, delayed primary, and secondary closure are described in detail and need not be referred to in this place.

Débridement, however, in faciomaxillary wounds, if ever done, should be sparing, for the facial tissues are nowhere in excess. Fortunately, the increased resistance of facial tissues to infection will about balance

Fig. 186.—Loss of Facial Tissues So Extensive, Coaptation Impossible, Wire Tension Sutures and Lead Plates Used.

Fig. 187.—Same Patient as Fig. 186 After an Interval of Seven Days.

this necessary compromise with the general surgical principle of complete débridement. Experience has also taught that cavities must be drained until the time for their closure. The closure of the wound by suture is the ideal toward which all surgical efforts are directed, for an open wound cannot be kept sterile and a closed one can rarely become infected. Where an actual loss of skin has occurred and the gap cannot be covered except by sliding or transferring flaps, it is dangerous to attempt such plastic procedures at the time of the primary operation. Tension sutures of silver wire exerting their pressure upon lead plates placed 1 inch or more from the wound margin will always prevent further retraction, and frequently will produce surprising results in the approximation of the tissues during the period of wound sterilization (Figs. 186, 187) and greatly help in the secondary closure of the wound.

Kazanjian[1] expresses the general opinion of oral surgeons in saying, "No attempt should be made to suture the soft parts with an idea of closing the gaps until such a time as union of the fractured parts in correct relation is well under way and permanent splints are adjusted." This does not mean a long delay, for every effort should be made to close the wound of the soft tissues before the beginning of scar tissue formation, *i. e.*, before the twelfth day.

Immobilization of the jaws in faciomaxillary wounds is one of the essentials of their treatment. This not only applies to injuries involving the bones but also to facial injuries in which there is no bone involvement. The emergency splint supplied to the A. E. F. could well be adopted by civil and industrial hospitals. It consisted of a metallic plate in the form of a narrow trough which could be so bent at its center as to form a **V**-shaped interdental splint, and when dental modeling composition was placed upon the upper and lower surfaces and the teeth allowed to become embedded in it a very efficient and practical temporary fixation was provided. Such fixation of faciomaxillary wounds is followed by the disappearance of the pain which always accompanies the slightest movements, especially in the presence of fractures, as in the motion of swallowing, talking, or coughing. Further, such fixation is the best protection against immediate hemorrhage, as that which follows injuries to the vessels, or late hemorrhage resulting from the traumatization of the blood-vessels by the sharp edges of the bones. Immobilization definitely limits the process of infection and suppuration here as it does in all body tissues. Finally, the earlier the fixation is provided, the earlier consolidation will occur.

Diet.—The feeding of patients wearing interdental splints necessitates a special diet, usually liquid, though in a few instances a special soft diet can be taken. At the American Ambulance liquids were given every two to four hours, depending upon their concentration; a rubber tube introduced through the nose far back into the pharynx provided a practical method of administration.

SUMMARY OF DIETARY

Acute Injury of the Jaw

Liquid through a tube every two hours during the day, every four hours during the night.

Milk, 1 pint; 1 egg; or strong soup, or Benger's food with egg or Bovril made with milk, or thin arrowroot with Valentine's Meat Juice, or boiled custard, with the addition of stimulants—brandy or port wine as ordered.

Basis of dietary for twenty-four hours: Milk, 4 pints; eggs, 4; soup, 2 pints.

Semiliquid Dietary for Convalescent Patients:

Same as above in four-hourly feedings.

In addition: Baked custard; strained fruit juice or stewed fruit; jelly; bread and milk; porridge.

Convalescent—Semisolid:

Breakfast, 7.45 A. M.: Porridge, 1 pint, with milk; sugar; tea; thin bread and butter. Alternative bread and milk or gruel.

Luncheon, 11.00 A. M.: Bread and milk or beef-tea with bread.

Dinner, 1.00 P. M.: Minced meat, mashed potatoes, greens, milk pudding.

Tea, 4.00 P. M.: Tea, or bread and milk; 2 eggs lightly boiled, poached, fried, or scrambled. Bread and butter.

Supper, 7.00 P. M.: Cocoa, 1 pint; or bread and milk.

Anesthesia.—Though regional and conductive anesthesia* with novocain and adrenalin are the methods of choice, when these are not practical, intranasal or intrapharyngeal ether anesthesia can be satisfactorily employed.

COMPLICATIONS

Hemorrhage.—Slight secondary oozing from these wounds is a common occurrence. When packing, clamping, or ligation of the bleeding point does not control the hemorrhage a more radical course must be instituted. As an adjunct to packing Kazanjian[2] suggests a specially devised clamp which consists of a heavy piece of wire from 8 to 10 inches long bent to a **U** shape, with a finger or pad of dental modeling composition or vulcanite rubber on each end. The clamp is adapted by bending it so that one end presses over the packing, the other presses externally at a corresponding point under the chin between the hyoid bone and the lingual aspect of the mandible. Ligatures or elastic bands about the arms of the clamp will give the desired amount of pressure. Unfortunately, it is not always possible to determine the artery from which the bleeding occurs in these wounds. In a general way, (1) bleeding from the floor of the mouth comes from one or both lingual arteries; (2) bleeding from between the fragments of a fracture of the interior maxilla comes from the inferior dental artery; (3) bleeding from the cheek or lip originates in a branch of the facial; (4) bleeding from the pharyngeal or tonsillar region or from the antrum of Highmore can only be controlled by ligation of the external carotid just above the origin of the superior thyroid. Experience has shown that in hemorrhage from the lower jaw or the floor of the mouth ligation of the external carotid on one side only is usually inadequate, as hemorrhage frequently recurs from the other side. Ligation of both the lingual arteries has given the best results in this condition.

Pulmonary complications should be a rarity if oral cleanliness and wound sterilization are adequate. Valadier reports but one rib resection for empyema in 1010 cases.

RECONSTRUCTIVE SURGERY OF THE SOFT TISSUES†

The earliest possible replacement, after injury, of the lacerated tissues in their normal anatomic position or the best approximation to such relations as can be obtained, is the greatest help to later plastic procedures. In general, it may be said that adequate primary surgery to faciomaxillary wounds is undertaken too late, and it is equally true that, as a rule, subsequent surgical procedures are undertaken too early. Secondary repair of the soft tissues should not be undertaken until the

*The term "conductive anesthesia" is applied to the infiltration with a local anesthetic of the trunk of the nerve supplying the operative area at a distance from proposed incision, as injection of the inferior dental nerve where it enters its bony canal in the inferior maxilla.

† It is by the courtesy of Major George M. Dorrance, M. C. U. S. A., that it has been possible to exhibit in this article the photographs of the plastic surgery of Major Gillies, R. A. M. C., with whom he was associated while detailed to the Queen's Hospital, Sidcup, England.

wounds have been shown to be surgically sterile according to the standard of Dakin and Carrel and some form of permanent interdental splint has been applied.

In the chapters upon Plastic Surgery (Vol. V, p. 879, and Vol. VI, p. 929) the principles of this type of reconstruction are described in detail. In the war wounds the standard methods of skin-grafting of Wolff and Thiersch have not been improved upon and have uniformly given satisfaction. The large areas of lost tissues which have frequently followed these massive gunshot wounds have made it necessary to employ extensively sliding and pedunculated flaps from adjacent parts, and at times from such distant parts as the scalp, neck, chest, and arm. Experience has shown that when planning flaps skin from adjacent tissues are always to be preferred to those from a distance because of their similarity in texture. Major Gillies,[3] R. A. M. C., attached to the Queen's Hospital, Sidcup, has modified the technic of the use of pedunculated flaps by sewing together the free edges of the long pedicle, thus forming a tube. This is shown in Figs. 188 and 189. By thus eliminating the usual contact of the inferior raw surface of the subcutaneous tissues of the pedicle with the epithelial surface of the underlying skin, and having epithelial surfaces only in contact, the usual maceration, infection, and often suppuration between the epithelial and subcutaneous surfaces are avoided.

In planning flaps for plastic facial surgery, skin must be chosen that closely resembles the skin of the area to be covered in color, shade, elasticity, thickness, direction of its fibers, hair, and number and size of its pores.

Another distinct contribution to the technic of plastic surgery has been Esser's epidermic inlay in combination with dental modeling composition. This procedure is invaluable in:

1. The enlargement of the conjunctival sac.
2. Construction of a part of the lobe of the ear.
3. Enlargement of the mucous membrane of the mouth, which is so often destroyed and is always replaced by crippling scar tissue.
4. Enlargement of the mouth cavity.
5. Defects of the hard and soft palate.
6. Covering of various forms of skin-flaps.

The application of this method is shown in Figs. 190, 191,* taken from the service of Major George A. Dorrance, at U. S. General Hospital at Cape May.

Esser believed that the unsuccessful results from the use of the Thiersch graft were largely due to the irregular growing together of the skin and grafts and the formation of scars in the granulating surface. He devised a method of applying the grafts evenly and keeping them immovable, under equal pressure, on the wound for some days. After creating aseptic hollows by undercutting the skin around the margins

* Figs. 190–192 are exhibited through the courtesy of Major George M. Dorrance and are a part of the records of his work at U. S. General Hospital, Cape May, N. J.

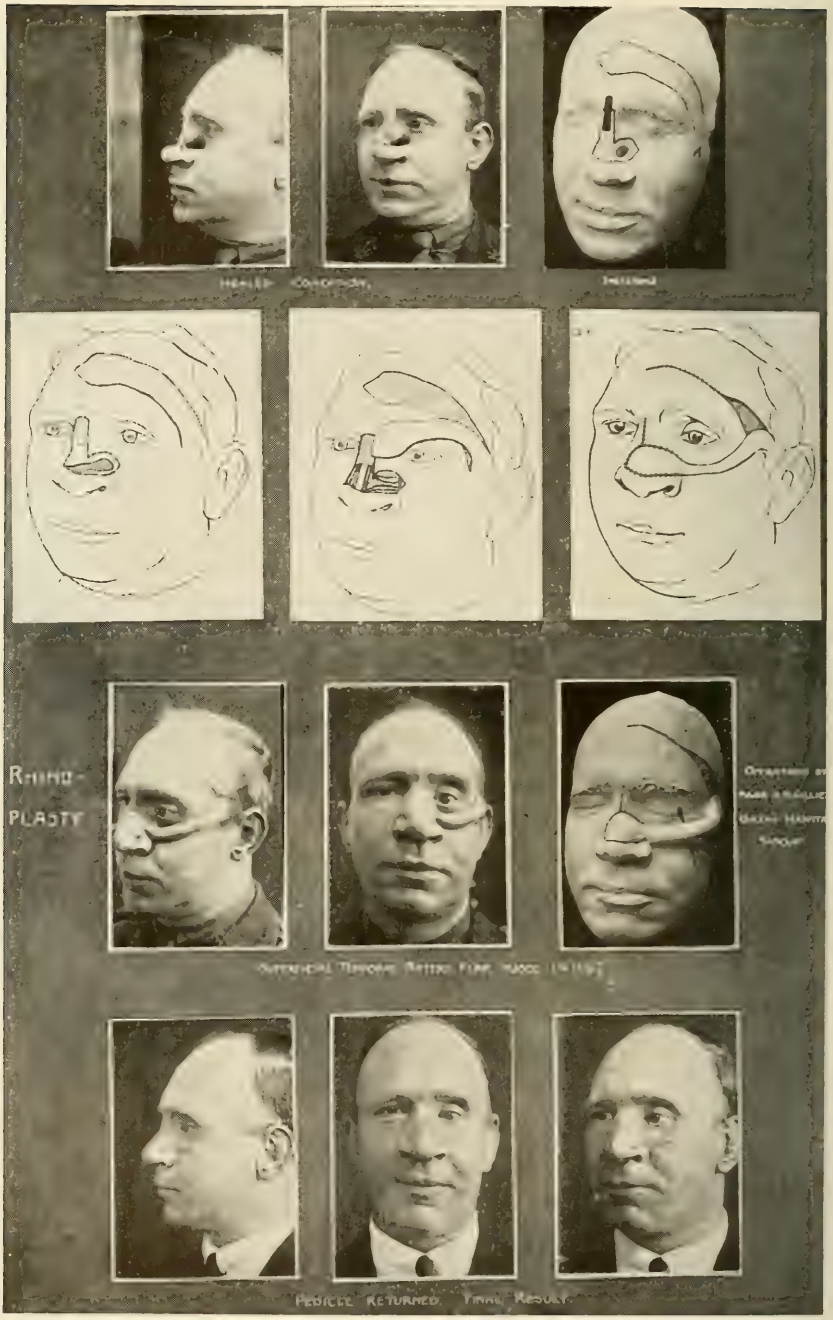

Fig. 188.—The Principle of Converting Into a Tube the Pedicle of Transplanted Flaps (Dorrance.)

of the wound the loosened skin-flap is elevated and this cavity and the surface of the wound accurately filled with a mold of dental model-

ing compound. Very thin Thiersch grafts, preferably taken from the under surface of the upper arm, are then laid upon the mold of model-

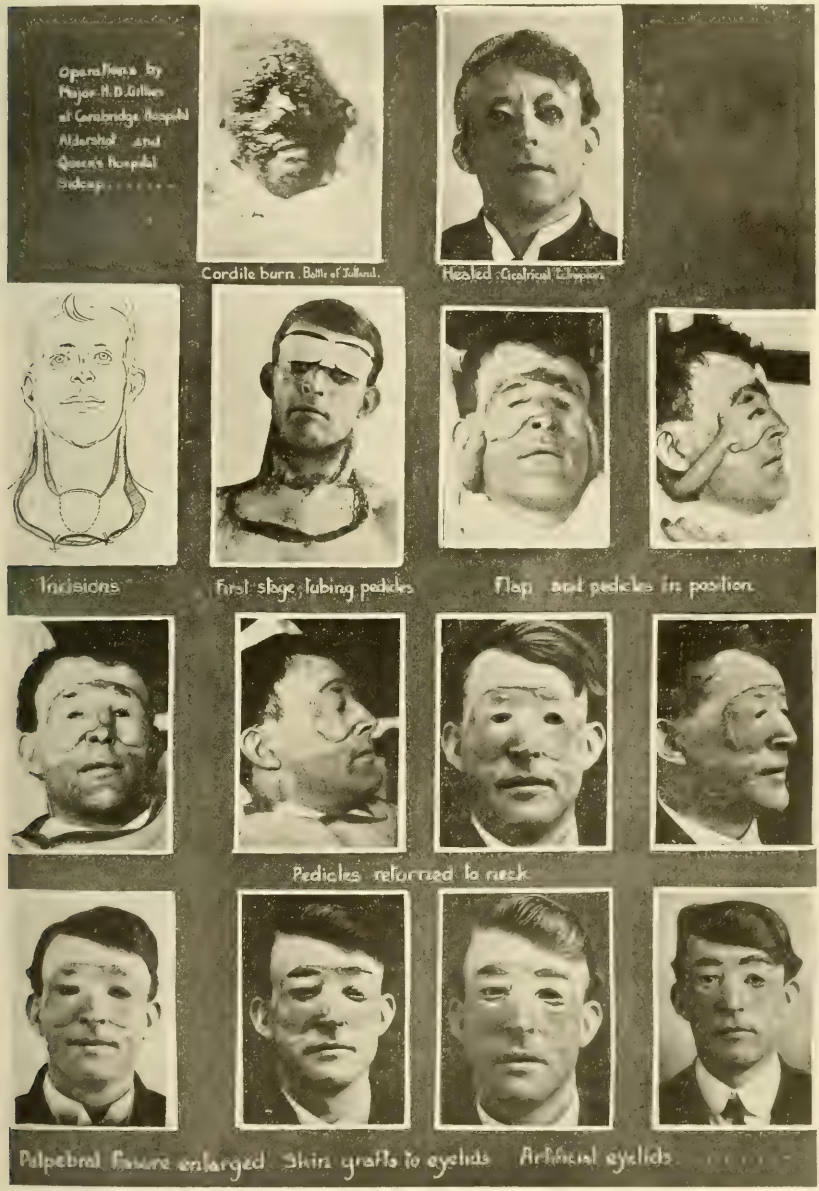

FIG. 189.—THE TUBING OF THE PEDICLES OF TRANSPLANTED FLAPS. (Dorrance.)

ing compound (the raw surface of the Thiersch graft is outward, the epithelial surface in contact with the modeling compound). The graft-covered mold is then placed on a surface wound as one would a watch

crystal; in deep wounds it is actually buried and held in place by suturing the incision. About fourteen days later an incision is made over the thinnest portion of the mold and the modeling compound is removed.

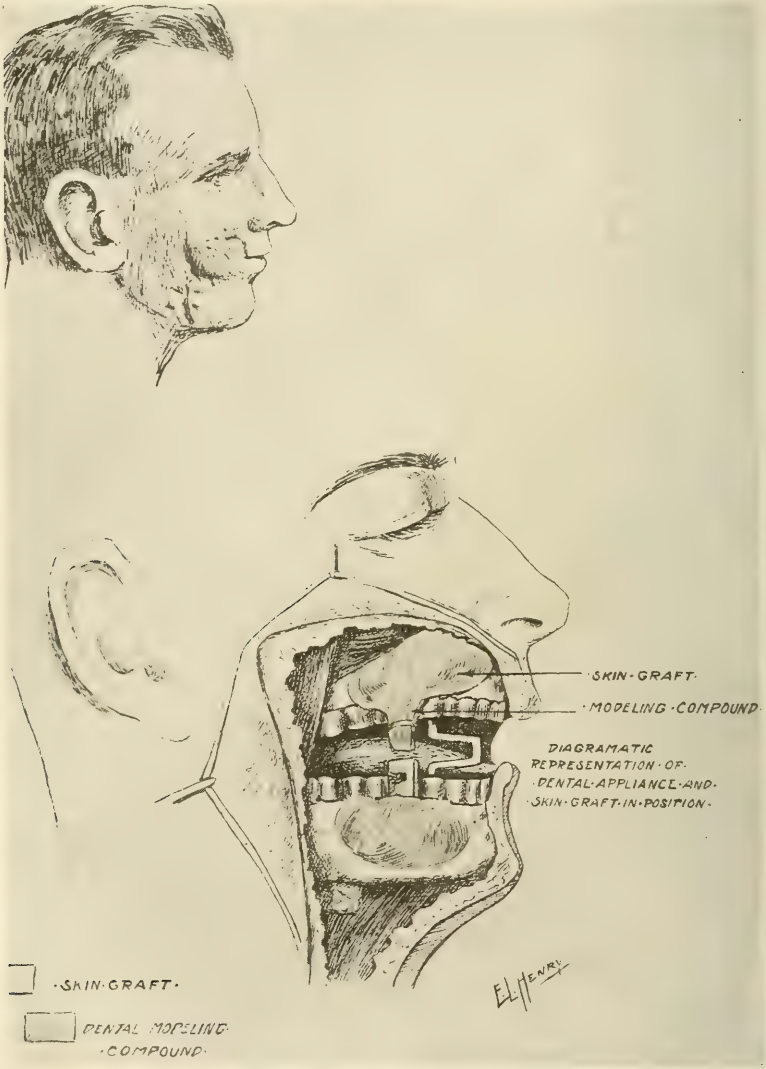

Fig. 190.—Illustrating the Esser Epidermic Inlay. (Dorrance.)

The illustrations of its application in the enlargement of the mucous membranes of the mouth as shown in the photographs of Major Dorrance cover all of the principles. After removal of the scar, incisions are made in the buccal tissues which are exactly the size of the desired cavity, no provision being made for shrinkage. An exact mold of the new

cavity is then made of the modeling compound, but an improvement of Esser's original technic, suggested by Major Gillies, R. A. M. C., is to provide a dental appliance for the fixation of the mold to the adjacent teeth instead of sewing it into the tissues.

To those who struggled in the early years of the war to overcome the crippling bands of scar tissue in the mouth this method came as an inspiration.

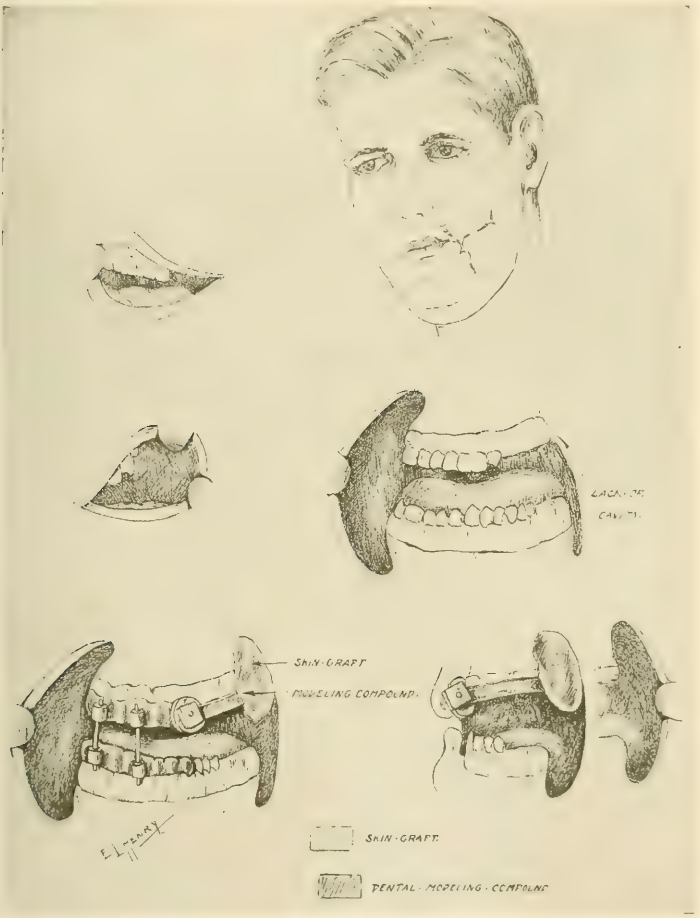

Fig. 191.—Illustrating the Esser Epidermic Inlay. (Dorrance.)

Cartilaginous Transplants.—During the war cartilage transplants have been used with great success in restoration of deformities resulting from the loss of bone. Figure 192 illustrates the transplantation of a section of the sixth costal cartilage to replace a loss of bone in the supra-orbital ridge. As inlays in the reconstruction of the eyelids, nose, ears, and such small bony defects as shown in Fig. 192 it has its greatest value, but many have used it in the repair of defects in the jaws. Firm bony union never follows its use, and the general opinion is that

for the maxillæ, where bony rigidity is a necessity, bone transplantation is indicated. Morestin[4] says that cartilage transplants are easily resected, the resulting wound being closed with layer sutures. No untoward effects have ever been reported, even when all three cartilages have been removed. Cartilage lends itself to easy manipulation, being easily cut into any shape and size with a knife. Sheets, rods, arcs can be fashioned with precision, and no special instruments are required for their preparation. The transplanted pieces are readily grafted, they

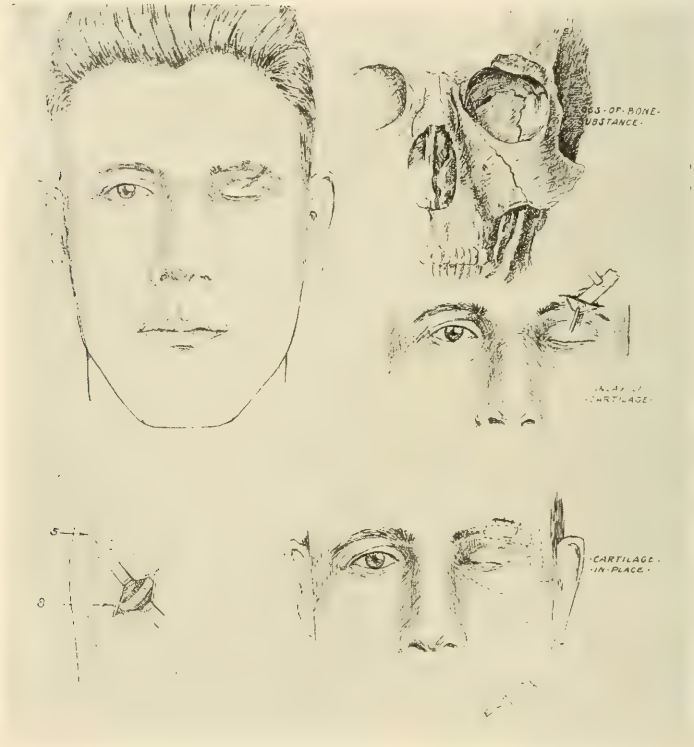

Fig. 192.—Illustrating a Cartilage Inlay. (Dorrance.)

live their normal life, rapidly adapt themselves to their new conditions, and live indefinitely without being resorbed, as in the case of bone, and they do not decrease in size. The transplanted pieces therefore should be of the exact size desired to fill the defect. Cartilage may be taken from another person, but care is necessary to follow the laws of blood grouping which apply equally to the tissues.

REPAIR OF DEFORMITIES OF THE MOUTH, LIPS, AND CHEEKS

The principles of plastic surgery of face will be found in Chapter LXXVI, Vol. V, and Chapter CXLVI, Vol. VI.

Stomatoplasty, the restoration of the mouth; cheiloplasty, the formation of a lip; meloplasty, the reconstruction of a cheek, are almost in-

finite in number and variety because of the differences in the loss of tissue. Cheiloplasties especially require repeated operations and great patience both upon the part of the surgeon and the patient.

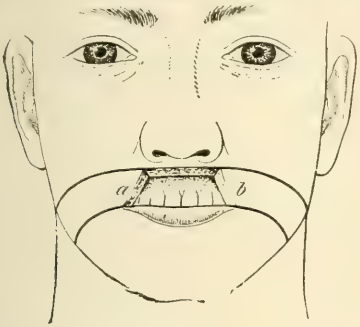

Fig. 193.

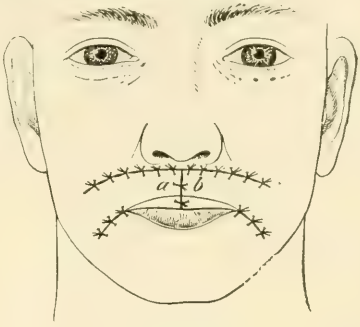

Fig. 194.

Figs. 193, 194.—Restoration of Upper Lip. (Roberts, "War Surgery of the Face.")

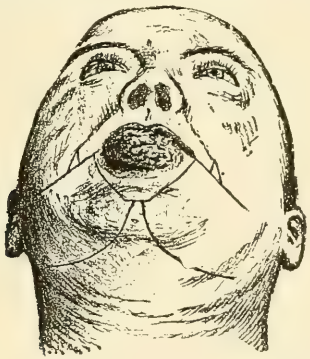

Fig. 195.—Dowd's Incisions for Making Lower Lip After Excision of Labial Tumor. (Roberts, "War Surgery of the Face.")

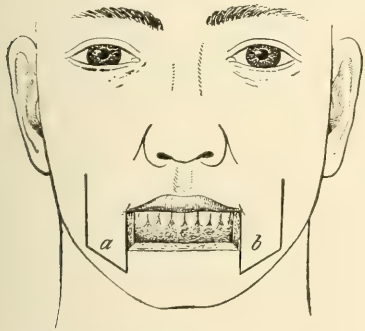

Fig. 196.

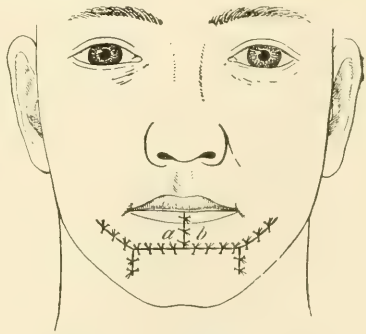

Fig. 197.

Figs. 196, 197.—Diagram of Method of Making Lower Lip from Tissue Over Mandible. Roberts, "War Surgery of the Face.")

The illustrations reproduced from Roberts' War Surgery of the Face (Figs. 193–207) represent diagrammatically the many phases of the

operation. Vermilion for the new-made lip is usually obtained from the mucous membrane of the mouth. Loss of mucous membrane from the

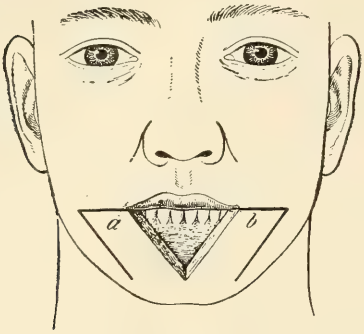

Fig. 198.

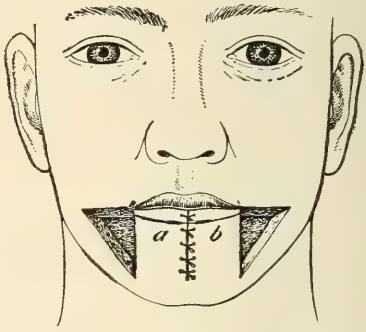

Fig. 199.

Figs. 198, 199.—Restoration of Whole Lower Lip. (Roberts, "War Surgery of the Face.")

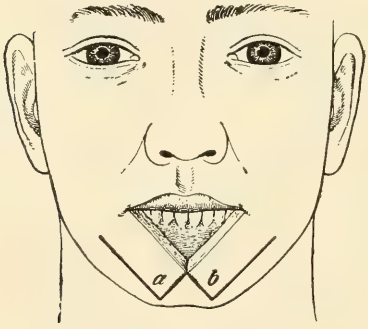

Fig. 200.

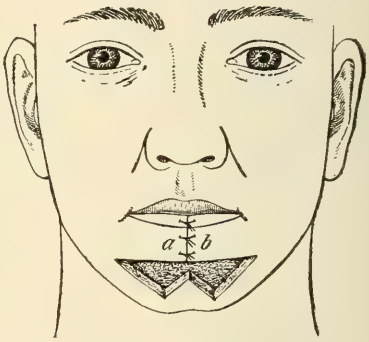

Fig. 201.

Figs. 200, 201.—Operation for Restoration of Lower Lip. (Roberts, "War Surgery of the Face.")

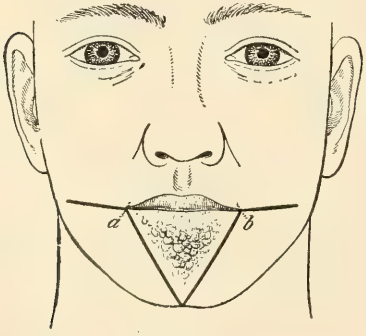

Fig. 202.

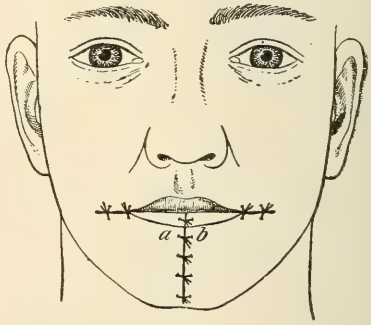

Fig. 203.

Figs. 202, 203.—Restoration of Lower Lip. (Roberts, "War Surgery of the Face.")

mouth is best replaced by Esser's skin-grafts after the manner described on page 213. Long flaps from the chest may be employed when the

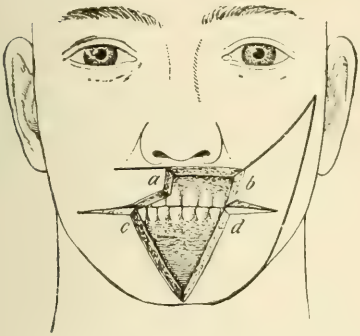

Fig. 204.

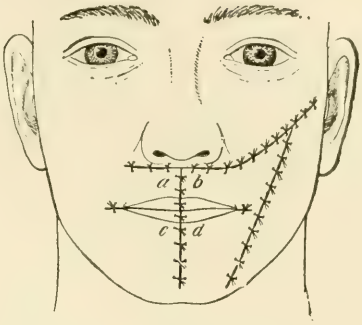

Fig. 205.

Figs. 204, 205.—Restoration of Both Lips. (Roberts, "War Surgery of the Face.")

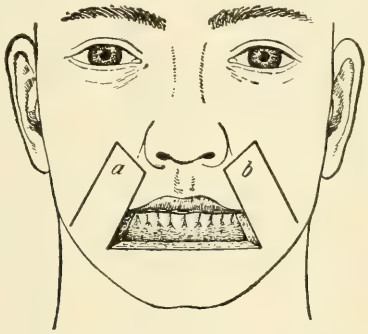

Fig. 206.—Another Method of Making Lower Lip from Cheeks. (Roberts, "War Surgery of the Face.")

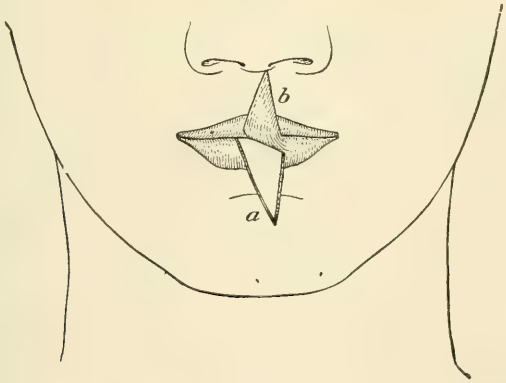

Fig. 207.—Diagram to Show Method of Transferring Wedge Flap from Lower Lip when it is too Bulky and the Upper Lip Needs Tissue to Increase its Breadth.

After the wedge (*b*) has grown fast in the incision (*a*) made in the upper lip, the pedicle supplying it with blood is severed. The wound (*a*) in the lower lip is closed with sutures at the time the transfer is made. Plastic correction of a tight lower lip may be made in a similar way from an upper lip and the adjacent cheek. (Roberts, "War Surgery of the Face.")

adjacent tissues of the face and cheek are so involved with scar tissue that they do not have the blood-supply necessary for successful plastic

flaps (Fig. 208). Where there is a loss of the underlying bony tissues such defects will have to be replaced, temporarily at least, with some

FIG. 208.—THE USE OF TUBULAR PEDUNCULATED FLAPS IN RHINOPLASTY. (Dorrance.)

form of dental appliance to permit of the proper modeling of the soft tissues. These same principles apply to meloplasty.

REPAIR OF DEFORMITIES OF THE EXTERNAL NOSE

The frequency of the entire loss of the external nose in the gunshot wounds of the late war is due to the general use of the hand grenade. This weapon and its resulting facial wounds created the neces-

FIG. 209.—WOUND OF FACE CAUSED BY SHELL FRAGMENT ADMITTED TO AMERICAN AMBULANCE, 1915, SERVICE OF MAJOR CLOPTON.

FIG. 210.—SAME PATIENT AS FIG. 209. (Clopton.)

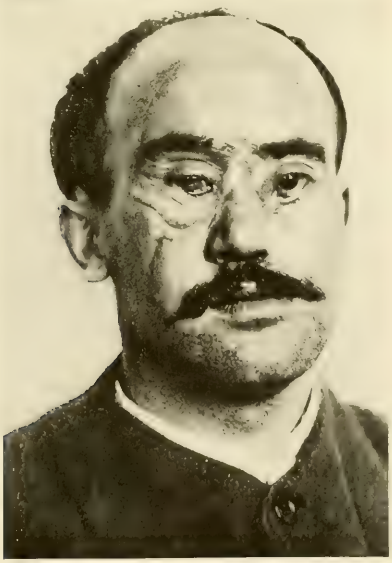

FIG. 211.—SAME PATIENT AS FIGS. 209, 210. PHOTOGRAPH TAKEN SEVEN MONTHS AFTER INJURY. (Clopton.)

sity for an unusual amount of faciomaxillary surgery. Surgeons before the war had little opportunity for experience in complete rhinoplasty, except for the few who had served in India, and this deformity was a curiosity.

The type of injury shown in Figs. 209–211, in which the soft tissues only were involved, shows the possibilities of early restoration. This was a shell wound of the face, the primary repair being done by Major Clopton, of St. Louis, in the service of the American Ambulance. But such opportunities are rare in military surgery, the usual problem consisting in a loss of alæ, cartilage, septum, columella, and even the nasal bones, as shown in Fig. 213.

Of the three standard methods of complete rhinoplasty—the French, Italian, and Indian—the latter is the one which has given the best results in the war. Its advantages are that it requires no constraint in the patient's posture as do the other two, it uses tissues adjacent to the area to be restored, and it permits of the preliminary inlay of cartilage into the flaps before they are cut, and thus makes possible results very much better than any other method.

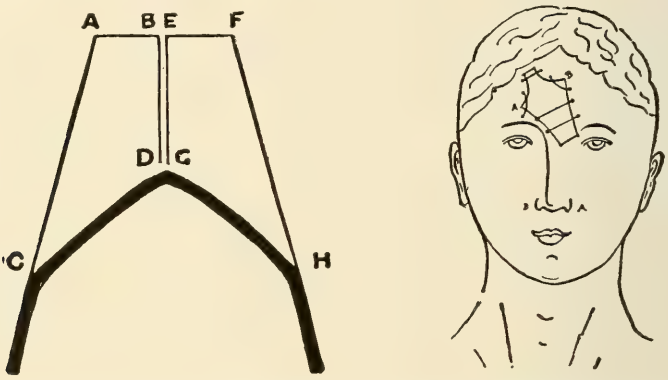

Fig. 212.—Diagram of Keegan's Operation for Rhinoplasty.

The flaps *C–A–B–D* and *G–E–F–H* are dissected from surface of nasal bones and bent downward as if on hinges at *C–D* and *G–H*. The second diagram shows Keegan's method of cutting the frontal flap and applying the sutures to the frontal wound. (From Keegan's "Rhinoplastic Operations.")

The original Indian operation, as described by Keegen (Fig. 212), is lacking in two essentials: there is no rigid replacement of the lost cartilage, and the soft tissue flap provided for the columella contracts as time passes, and there is a flattening of the tip of the nose. To overcome these two defects in the Indian operation Major Gillies, at a preliminary operation four to six weeks before the forehead flap is cut, inlays a piece of cartilage, which is to be the cartilaginous portion of the new nose, beneath the tissues covering the upper part of the nose. The lower portion of this cartilage inlay is at the level of the lower edge of the nasal bones. A second and a third piece of cartilage is embedded beneath the scar or skin near the crease of the new alæ (Figs. 213, 214). When the cartilage inlays have become fixed, in from four to six weeks, the tissues overlying the nasal bones are incised as in the Indian operation (Fig. 212) to provide an epithelial lining for the new nares, but, in addition, the previous cartilage inlay is also turned downward, its uncut attachment to the edge of the nasal bones acting as a hinge. Next the epithelial flaps overlying the second and third cartilage inlays are

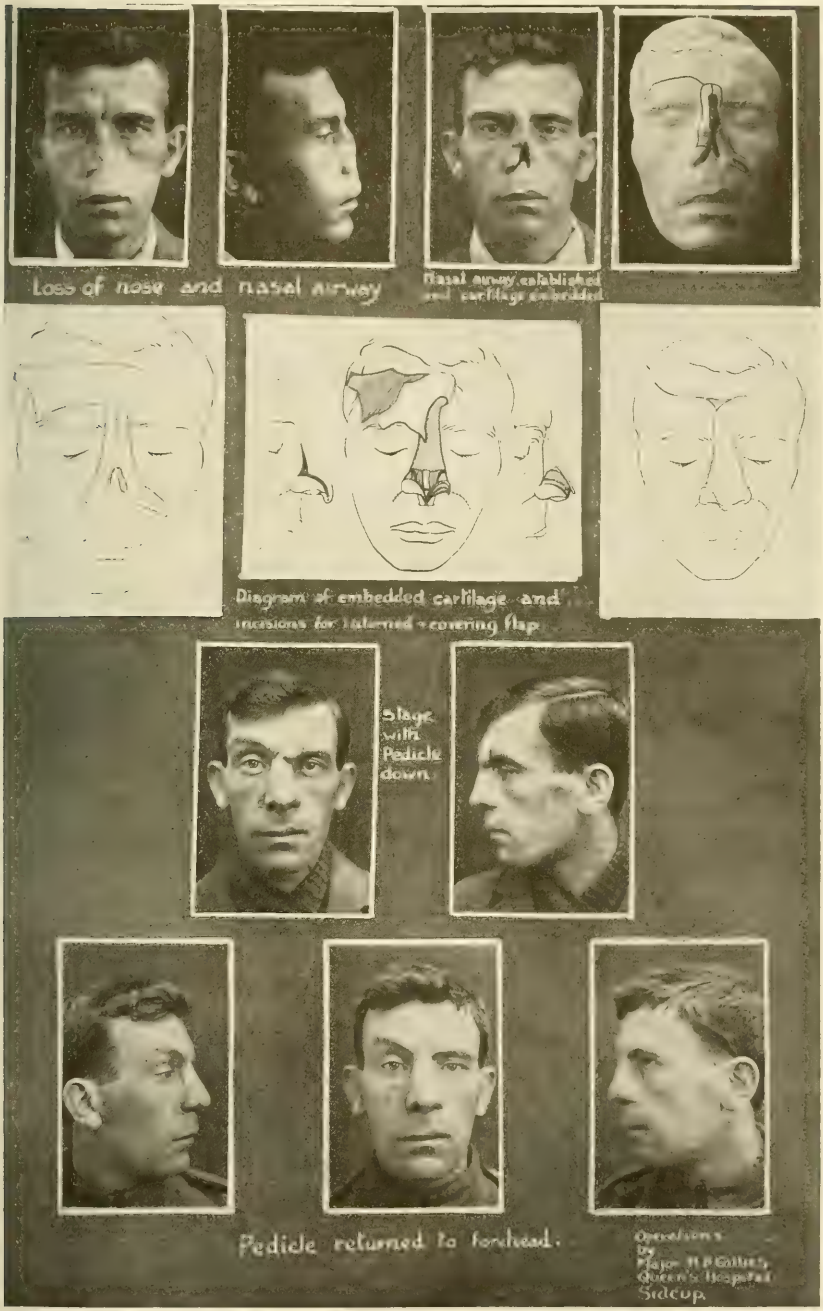
Loss of nose and nasal airway
Nasal airway established and cartilage embedded
Diagram of embedded cartilage and incisions for tube and covering flap
Stage with Pedicle down
Pedicle returned to forehead.
Operations by Major H. D. Gillies, Queen's Hospital, Sidcup.

Fig. 213.—Major Gillies' Modification of the Indian Method of Rhinoplasty. (Dorrance.)

cut and, together with the cartilage, are turned up to meet the lower end of the first cartilage inlay to form the tip of the nose. Thus not

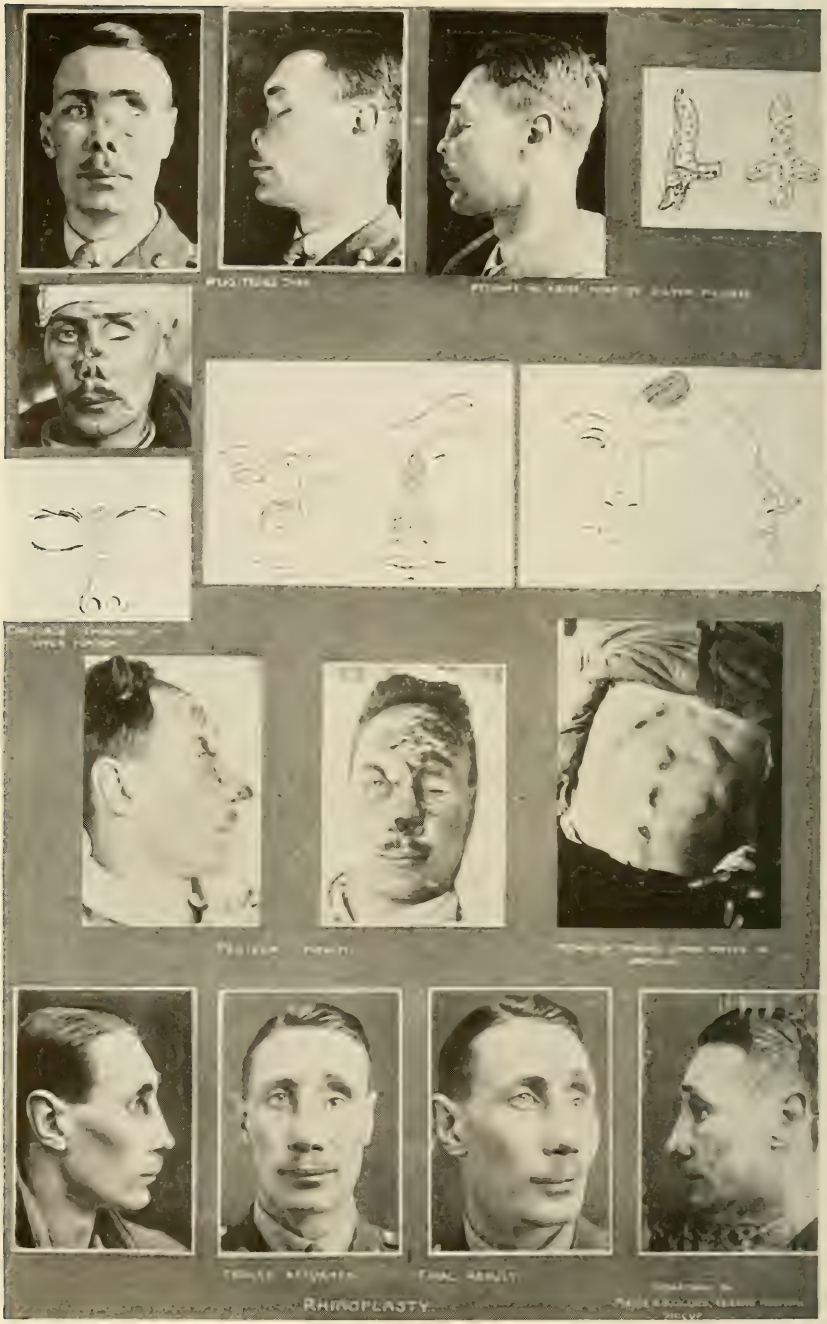

FIG. 214.—CARTILAGE EMBEDDED IN THE ABDOMINAL WALL AWAITING USE AS A TRANSPLANT IN NOSE. TRANSPLANTED TO FORM NEW SEPTUM IN GILLIES' MODIFICATION OF THE INDIAN METHOD OF RHINOPLASTY. (Gillies-Dorrance.)

only is the cartilage of the nose restored, but rigid cartilaginous supports for the tip similar to the legs of a tripod. This prevents the contraction of the soft tissues of the columella and consequent flattening of the nose.

METHOD OF MEASURING AND REGULATING THE SIZE AND SHAPE OF LOST PARTS OF THE FACE WHICH HAVE TO BE REPLACED

A cast is taken of the face and a model is made of the missing portion in plasticine on the cast by the sculptor. This reconstructed face is then made as a model on which the flaps are measured and the supports determined. These flaps are first cut in wash leather or elastic composition, and from them tinfoil flaps are made. These tinfoil flaps can then be boiled and used at the operation. In the case of nasal supports, such as the support for a new bridge, the requisite contour having been obtained in plasticine (allowing for the thickness of the tissue under which the cartilage is to be placed), a mold is made and a metal cast obtained. This is then used as a model, which is first inserted; it is followed by a piece of cartilage which has been cut the same size and shape. The cartilage, if not used at the time it is removed, is kept embedded in the patient's abdominal wall or in someone's else. It undergoes no change for at least a year (Fig. 214). All pedicle flaps are tubed by suturing the skin margins together. This device prevents sepsis or sloughing of the pedicle and improves the blood-supply.

PROSTHETIC FACIAL RECONSTRUCTION

Derwent Wood, a noted sculptor, has made a special study of facial masks to replace the lost features of the mutilated. His method is unique and deserves a description. The process, as he describes it, is as follows:

1. Casting the patient's face: In order to obtain the essential perfect fit of the edges of the plate to the patient's face a plaster mold of the face is first made.

2. Modeling: The mold having been obtained, it is dried, French chalked, and a clay or plasticine squeeze is obtained from the mold, giving a positive model of the patient's wound and the surrounding healthy tissues. This is fixed to a board on a modeling stand, and a sitting from the patient with the undressed wound is obtained. A reconstruction of the wound in every detail is established, and when completed, he proceeds to cast the model and procures the plaster positive of the wound and its surrounding structure. Another sitting is obtained, and the portions which are to be hidden eventually by the metal plate are modeled in clay or wax, the edges being blended to the uninjured portions of the face, thus effectively masking any trace of the wounds. This is once more molded in plaster, and the edge of the proposed plate being marked on a negative, a cast is obtained, the edges trimmed to the marking, and the model is ready to have the artificial eye fitted to the lids; this is done from the back of the model. The plaster eyeball is dug out, the requisite thickness of lids carefully worked

down, the glass eye placed in position, and the edges of the lids made good with thin plaster.

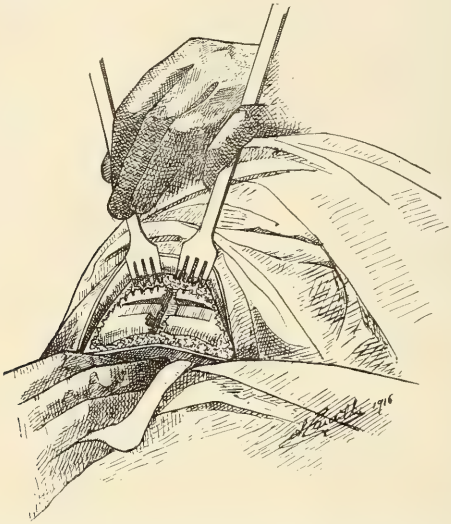

Fig. 215.—Groove Prepared for the Autogenous Bone-graft Inlay. (Lee.)

3. The plate: The model is now taken to the electrotyper, where an exact reproduction by galvanoplastic deposit is made in virgin copper

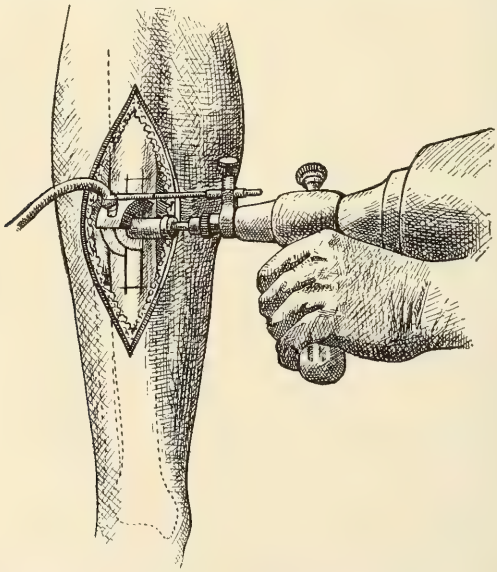

Fig. 216.—Obtaining Autogenous Bone-graft from Tibia. (Lee.)

$\frac{1}{32}$ inch in thickness. This is finally well coated with silver. Thin bands are soldered in on the back to plant the eye in place. The plate

is again fitted to the patient and strong spectacles are adjusted at the requisite angle to give a well-distributed pull on the plate. Large plates require an elastic band around the back of the head.

The final sittings are devoted to the pigmentation of the plate.

FRACTURES OF THE BONES OF THE FACE AND JAW

The principles underlying the treatment of all fractures, immobilization, and protection against infection must be followed in the surgical care of fractures of the face and jaws. The care of the *simple fractures*, which are a curiosity in military surgery, is described in chapters on Fractures, Vols. II, p. 75; VI, p. 160; VII, p. 415. The *compound fractures*, which are the rule in faciomaxillary injuries, are always infected to some degree, and the dribbling saliva, the fetor of the de-

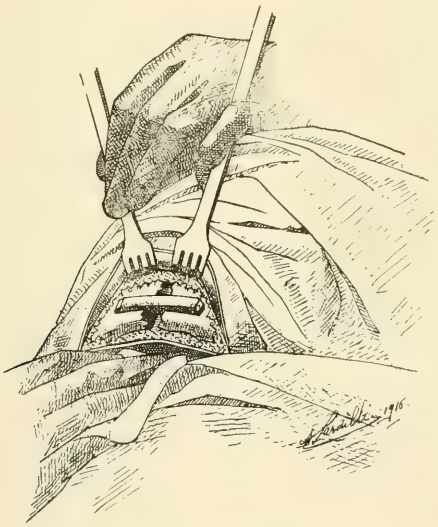

Fig. 217.—Graft in Place. (Lee.)

composing food and other secretions, the abscesses about the decayed teeth present unpleasant and difficult problems. Our war experience has shown that to the skilled dentist and oral surgeon can be delegated this task of oral cleanliness and fixation of the bone fragments, and in Chapter XXXVIII an outline of the methods used will be found.

To the surgeon remains the responsibility of closing the gap in the soft tissues as soon as the oral surgeon has completed his denture and the wound is surgically sterile. In the earlier years of the war it was advised to make every effort to close the wounds in the soft tissue even to sacrificing the normal occlusion of the teeth if necessary. Later, as the experience of the oral surgeons developed and their number increased, it became the general practice not to close the soft tissues until a functionally useful occlusion of the teeth was obtained.

Pseudo-arthroses.—It was certainly the accepted practice at the

close of the war to treat ununited fractures of the mandible by bone transplantation after the method of Albee. Wiring or the introduction of foreign bodies of any kind have given very unsatisfactory results. The grafting follows the usual technic of this procedure in other parts of the body.

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CHAPTER XXXVIII

THE RÔLE OF THE DENTAL SURGEON IN THE TREATMENT OF FRACTURES OF THE JAWS

By Eugene L. Darcissac, D. D. S., D. E. D. P., D. F. M. P.
Paris, France

During the war of 1914 to 1918 a great variety of cases of fracture of the jaws came under observation. These fractures, produced by missiles, are, with the exception of the simple or partial fractures, open, comminuted, complicated with more or less extensive loss of bony tissue, and often attended with great injury to the soft parts. "The complex nature of these wounds," says Hayes,[1] "involving the maxillæ with almost universal loss of substance, including the soft tissues of the face, has opened up a field of operation which has brought the general and dental surgeons into a far more intimate and interdependent service than ever before, and has demonstrated not only the advantage to be gained from, but the necessity of their mutual co-operation and consideration."

FRACTURES OF THE INFERIOR MAXILLA OR MANDIBLE

Muscular Actions.—A group of muscles is inserted in the lower jaw. Under normal conditions these muscles counterbalance one another perfectly, but after injury of one or several of these muscles they contract, with the result that during the downward movement of the inferior maxilla a lateral deviation takes place, or trismus of varying degrees of severity. If the bone is fractured the various fragments suffer displacement in opposite and varying directions.

Symptomatology.—Facial Asymmetry.—Disregarding for the moment the question of the gravity of the injuries to the soft parts, the most striking symptom is the facial asymmetry (Figs. 218, 224); the face deviates toward the seat of fracture. When the fracture is in the anterior portion the cheeks as well as the angulomaxillary region are flattened. This facial deformity is much more marked when the fracture is unilateral, whether it involve the horizontal or the ascending portion of the mandible (body or ramus). The lower portion of the face is, so to speak, attracted toward the lesion. In bilateral fractures (right and left) involving the body or the angle the mouth is held open (Figs. 219, 279).

Mobility.—During the first few days following the traumatism the fragments exhibit abnormal mobility, which is readily detected by palpation. Sometimes, however, the diagnosis is somewhat more delicate, and in certain fractures involving the angle there is no mobility at all,

and a roentgenographic examination becomes necessary in order to diagnose the fracture. Often the mobility of the fragments can be determined by merely asking the patient to open his mouth and displace the jaw in various directions.

FIG. 218.—FACIAL ASYMMETRY.

Fracture of the horizontal portion of the mandible, right side. The face deviates toward the seat of the fracture. (See also Fig. 224.) (After Hayes.)

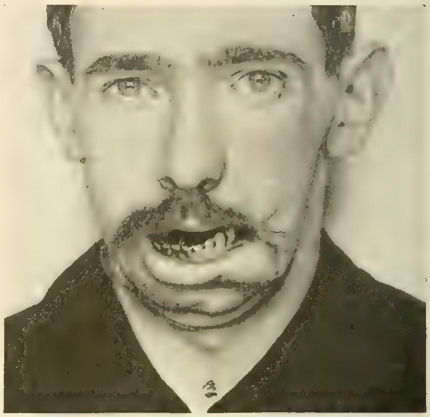

FIG. 219.—BILATERAL PSEUDARTHROSES (RIGHT AND LEFT) INVOLVING THE BODY OR THE ANGLE; THE MOUTH IS HELD OPEN. (After Stukl.)

Dental Arches.—The line of occlusion is broken at the point of fracture, sometimes in a vertical (Fig. 263) and sometimes in a horizontal direction (Fig. 261).

FIG. 220.—IN LATERAL FRACTURES THE PRINCIPAL FRAGMENT DEVIATES TOWARD THE INJURED SIDE. (After W. Davenport.)

Suppuration.—There is profuse suppuration. The pus is fetid and flows constantly from the seat of fracture, both from the wound of entrance and from the wound of exit.

Fragments.—The mandibular fragments shortly are subjected to two influences: muscular contraction and the process of repair. The

fragments are displaced toward the median line. This displacement varies considerably with the character of the wound and the seat of the lesion.

FIG. 221.—IN BILATERAL OR MULTIPLE FRACTURES THE MEDIAN FRAGMENT IS DISPLACED DOWNWARD BY THE DEPRESSOR MUSCLES. (After Darcissac.)

In fractures of the anterior portion the two fragments, right and left, are drawn toward one another and the tongue is caught as in a vise.

FIG. 222.—COMMINUTED FRACTURE OF THE HORIZONTAL PORTION OF THE MANDIBLE. (After Darcissac.)

In lateral fractures the principal fragment deviates toward the injured side (Figs. 220, 269) and downward (Figs. 263, 270). The posterior

fragment may assume the most curious positions. If it contains one or several teeth it may remain in a position of normal occlusion; or the fragment may be drawn inward toward the tongue, or sometimes outward along the inner surface of the cheek (Fig. 261). In bilateral or multiple fractures the median fragment is displaced downward by the genio- and the mylohyoid muscles (Fig. 221).

Roentgenography.—Roentgenographic examination is the most valuable aid in throwing the light on the extent and nature of the bony and dental lesions. The seat of fracture (Fig. 222) is clearly seen on inspection of the photograph. If there is no loss of substance, the bone is fissured in one or several directions, forming large splinters which

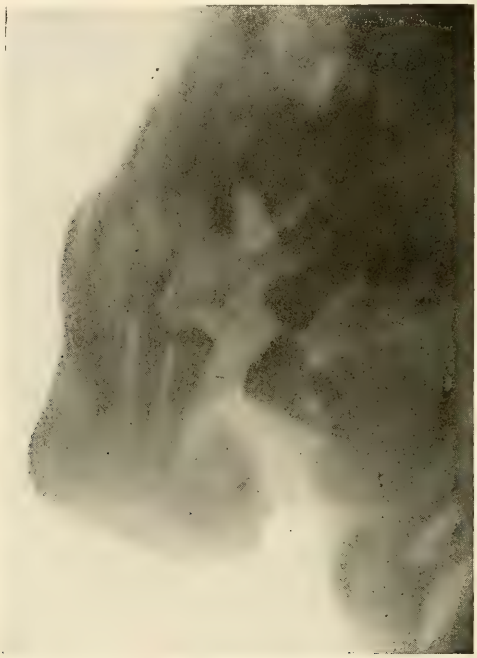

FIG. 223.—FRACTURE OF THE HORIZONTAL PORTION OF THE MANDIBLE WITH LOSS OF SUBSTANCE. The very last molar on the posterior fragment will be temporarily kept. (After Darcissac.)

interlock (like the cogs in two cogwheels), with or without displacement (Fig. 222). These conditions are favorable to firm union. Sometimes the missile carries off a more or less extensive portion of the bone, leaving only a few osseous elements between the fragments; these must be carefully preserved. In other cases there is total loss of substance over a varying extent of bone (Fig. 223). Teeth at the site of the fracture are fractured, or the roots may be merely denuded and deprived of their bony sheath to a variable extent (Figs. 222, 223).

Course.—The clinical course of a lesion of the jaws is very rapid. If it is left to itself, the fragments become displaced and are displaced toward one another. Quite movable at first, their mobility diminishes

notably in a few days, when reduction of the fracture becomes impossible. Unless the surgeon intervenes the fragments generally unite in vicious positions; or, if there has been extensive loss of tissue or marked separation of the ends of the bone, a pseudarthrosis of varying degree results. Complications due to infections are rare, and hemorrhage is to be feared only during the days immediately following the traumatism. We have, however, observed a few cases of grave secondary hemorrhage.

The injured soft parts also undergo changes incident to the reparative process. Newly formed contractile scar-tissue is fused with the bony fragments, resulting in cicatricial adhesions and bands of varying extent, which later complicate the treatment. The density of this scar-tissue is sometimes so great that it is difficult to distinguish bone from the surrounding soft tissues, the two forming one solid mass.

The periosteum is endowed with considerable osteogenetic power, and one occasionally sees small, adherent splinters of bone or portions of periosteum effect the repair of considerable gaps in the bone as soon as a rational treatment is instituted.

FRACTURES OF THE SUPERIOR MAXILLA

A vertical fracture may affect the alveolar margin and may extend through the entire body of the superior maxilla. Horizontal fractures may be situated at the level of the bridge of the nose or lower down, in the region of the alveolar crests. These fractures result from penetrating wounds of the face, or else they are simply indirect contact fractures. Sometimes the bodies of the superior maxillæ are perforated or abraded in severe explosions; the maxillæ suffer dislocation and separation from the rest of the facial skeleton at the level of the base of the nose (Figs. 239, 242).

Symptomatology.—The important symptoms are hemorrhage, hematoma, and infra-orbital edema.

Mobility is distinctly detected on palpation; also when the patient alternately brings the jaws together and lowers the mandible, the entire upper dental arch being then displaced vertically. In more severe cases the maxillary mass falls down and is displaced by the slightest movement.

Fragments are, in general, displaced downward and backward; the entire upper dental arch suffers backward displacement (Fig. 247).

TREATMENT OF FRACTURES OF THE JAWS IN GENERAL

The treatment of fractures of the jaws must always be viewed both from the surgical and from the dental standpoint. It is impossible for the general surgeon unaided to accomplish the proper fixation in cases of fracture of the jaws (Sébileau). The co-operation of the surgeon and the dental surgeon is absolutely indispensable. The treatment must satisfy several desiderata:

1. Disinfection of the mouth must be effected by means of prophylactic treatment, proper treatment of the teeth and their roots, and by surgical intervention.

2. Perfect drainage of the septic fluids must be provided.
3. Reduction of the fracture.
4. Coaptation of the fragments.
5. Fixation of the fragments in their normal positions.
6. Replacement of lost tissue and substitution of prosthetic appliances for the lost dental organs.

Disinfection of the mouth is achieved by frequent irrigation and gargling, every two hours, before and after each meal. Boiled water with hydrogen-dioxid water, potassium permanganate, 1 : 5000, or simply boiled water is used. The teeth, gums, tongue, and all the oral mucous membranes must be cleansed by the dental surgeon with absorbent cotton pledgets. At the same time all broken and loosened teeth, and teeth with denuded or broken roots, are extracted if the patient's general condition permits. Such teeth must always be extracted if the roentgenographic examination indicates that the roots are in direct relation with the lesion of the bone; but in the case of simple or indirect contact fractures any teeth near the seat of fracture may be preserved, because they usually have not suffered any serious injury, and it is only the alveolodental ligament that is torn. In some cases, when one of the fragments contains only one or two teeth which cannot be saved, extraction may be postponed during the temporary union of the fragments until after the fracture has been reduced (Fig. 223).

All hasty and premature surgical intervention and curetments in the dark must be avoided. Splinters of bone even when they are attached only by the merest shreds of tissue must be saved, and only such extracted as are entirely free and mobile. All foreign bodies are to be removed. Bone sutures are absolutely contraindicated at the beginning of the treatment.

Reduction.—Primary Reduction.—Fractures of the mandible must be reduced as early as possible, that is to say, during the first few days following the injury. Reduction must be complete and absolute. Suppuration is not a contraindication to immediate intervention. It is quite easy at this time to replace all free fragments in their normal positions and maintain them so. The question arises: Shall the fragments be replaced in their normal positions in all cases? The answer will depend (1) on the gravity of the bony lesion, and (2) on the number of teeth that can be brought into occlusion.

Two grave consequences of fractures of the jaws must be avoided: (1) pseudarthrosis; (2) vicious union. Hence, (1) if there is no loss of bony tissue, as shown by the roentgenogram, the fracture must be completely reduced; the fragments replaced in their normal positions; the remaining teeth will then articulate with their opponents. (2) If the bony lesion is extensive, that is, if there is loss of substance, pseudarthrosis is to be feared, and measures must be taken to approximate the fragments, or at least one of the fragments, in order to avoid such a disaster. If there are enough teeth remaining on the two fragments as well as on the upper jaw, it is best, as a general rule, to replace the fragments in their normal positions; for we occasionally see extensive

defects in the bone undergo repair with astonishing rapidity, owing to the presence of unsuspected splinters which still adhere to the fragments and suffice to restore the continuity of the mandibular arch.

Coaptation.—In other cases, however, measures must be adopted to promote approximation of the fragment which contains teeth, providing articulation is good enough from the functional standpoint. In lateral fractures the main fragment must be replaced in its normal position, while the smaller fragment, which carries no teeth or only one or two, must be assisted in its normal anterior displacement in order to obtain better coaptation.

To summarize: When there is a loss of bony substance, fragments which have no teeth or no opposing teeth must not be reduced; on the contrary, natural displacement of such fragments toward the median line must be effected in order to obtain better contact between the ends of the bones. Later the articulating surface can be restored by means of various prosthetic appliances.

The site of fracture, the roentgenogram, the number of teeth remaining in each fragment, the presence or absence of opposing teeth are all factors to be taken into account in determining the line of treatment in each particular case.[2]

Secondary Reduction.—After two or three weeks immediate reduction is impossible. The dental surgeon must then depend on the slow, methodic action of the various orthodontic appliances. The extent to which ossification has taken place in the callus is shown by the roentgenogram and must be our guide in the choice of appliances.

Late Reduction.—Finally, still later comes the period when reduction becomes impossible; the fragments are in a vicious position and have united either by a fibrous ligament of greater or less density or by a bony callus. In these cases the evolution of the fracture is finished, resulting in serious consequences.

At this stage what has been said in the section on Primary Reduction must be our guide. If articulation is good enough from the functional standpoint, it is wiser not to intervene surgically, in order to avoid the possible occurrence of a loose pseudarthrosis, the consequences of which would be even more serious. The only thing left for the dental surgeon in such a case is to design a more or less ingenious prosthetic appliance, either fixed or removable, to ameliorate to a certain extent the patient's functional disability.

If the result thus obtained is unsatisfactory or insufficient the only possibility remaining is surgical reduction of the fracture or osteotomy (section or disarticulation of the bone—Morestin), or section of the fibrous ligament, followed immediately by the application of some appliance to secure fixation.

Fixation must be absolute and secured as soon as possible. Immediate and complete immobilization is the only rational treatment of fractures of the inferior maxilla in war surgery. The more extensive the bony lesion, the more complete and more prolonged must be the immobilization. The length of time during which immobilization can be

kept up will depend on the patient's age. In young, strong subjects, of course, union takes place very quickly.

PROSTHETIC METHODS FOR REDUCTION AND FIXATION

Preparation of Cast.—Plaster of Paris undoubtedly takes the best impression, but it is not always most suitable. There may be cases in which various plastic preparations used in dentistry may have to be employed. The impression is taken all in one piece; but when the displacement of fragments is too great, an impression of each fragment must be taken separately.

Reducing the Fracture on the Model.—This procedure is applicable when the fracture can be reduced and when there are enough teeth in the two dental arches to ascertain the respective positions of the fragments. After both the superior and inferior impressions have been taken the model is cut at the seat of fracture and the two parts placed in normal occlusion. The model thus obtained is then used for preparing the fixation gutter-splint (Case No. 9).

FIG. 224.—VULCANITE SLING IN PLACE. (After Darcissac.)

Reducing the Fracture in the Mouth.—When the number of points of orientation is insufficient, that is to say, when the dental arches do not contain a sufficient number of teeth, the following procedure is employed: An impression is taken of all the fragments together or of each fragment separately. On the models thus obtained a metal or vulcanite gutter-splint is prepared for each fragment, having on its anterior portion a metal extension to enable one to identify its position on the impression. The operator places the gutter-splints and holds the fragments in their normal position, while an assistant pours plaster between the gutter-splints in order to fix their respective positions. To the impressions thus obtained the original models are assembled, adjusted, and fixed in their corrected position (Case No. 18 "buccal atresia").

Extrabuccal and Intrabuccal Appliances.—In the treatment of various types of fracture of the jaw we must choose for each particular case the appliance which will secure rapidity of reduction and perfect fixation. The choice depends chiefly on the number of teeth remaining in the two dental arches and on the gravity of the lesion.

These appliances are divided into three classes: 1, Extrabuccal appliances; 2, intrabuccal applicances with the point of support outside of the mouth; 3, intrabuccal appliances with the point of support inside the mouth.

Extrabuccal Appliances.—*Sling or Bandage* (Fig. 224).—The vulcanite sling is a most useful adjuvant in the treatment of fractures of the jaws. It insures more perfect immobilization and distributes the pull and completes the action of the system of intrabuccal fixation. We advise it in all cases of fracture of the mandible, as it immobilizes the mandible in normal occlusion. This tends to lessen the undesirable tension which the metallic gutter-splints often exert on the remaining teeth. The sling is sometimes the only treatment in horizontal fractures (Guérin's fractures) of the upper jaw.

Chin-supports of metal, plaster, or vulcanite. These appliances are made of a stamped metal or vulcanite gutter-splint encasing the outer portion of the jaw-bone and held in position by tapes or rubber bands supported on the cranial vault. A plaster chin-support is made by incorporating liquid plaster in strips of gauze and modelling the whole on the outside of the face. Appliances of this kind have proved valuable at times, but have been used very little in the course of this war.

Intrabuccal Appliances with the Point of Support Outside of the Mouth.—(*a*) With the point of support on the lower portion of the jaw. Their use is indicated in fractures of the mandible when there are not sufficient teeth remaining to secure satisfactory fixation of the fragments. They are made on the principle of Kingsley's apparatus and are used solely for fixation (Fig. 260). (*b*) With the point of support on the cranial vault. This type is indicated in severe fractures of the upper or lower jaw (Figs. 240, 241, 243, 245), and for the purpose of fixation in rhinoplastic work, when there are no points of support available within the mouth (Fig. 284).

Like Kingsley's apparatus, it consists of a gutter-splint which encases the fragments and is provided with two lateral extensions parallel with the line of occlusion. These extensions are attached to a scull-cap or helmet. Immobilization is secured simply by means of tapes tied together at the top of the head (Fig. 245).

Intrabuccal Appliances with the Point of Support Inside the Mouth.—Extrabuccal appliances are used only in exceptional cases. Intrabuccal appliances are simpler, less uncomfortable to the patient, and make the treatment more methodic and more speedy.

Metal Ligatures.—The writer has used metal ligatures for reduction and fixation very frequently during the recent war. As to fixation, it is absolutely necessary that the two dental arches interlock in order to maintain the fragments in their normal occlusion, provided there are enough teeth in the two arches.

Intermaxillary Ligatures.—Bronze wires, such as are used in orthodontia, are used for making little hooks around the necks of the teeth. The thickest wires should be selected. They are made as follows: The wire is passed around the neck of the tooth and the two extremities are twisted together with forceps. The double wire obtained by thus twisting the two wires is then bent toward the free border of the tooth and cut off at that point. Then with smooth forceps this double wire is bent on itself so as to form a hook (Figs. 267, 268). In wiring the inferior

maxilla these hooks are attached to the front teeth of the two arches. A smaller wire is then used to bind together, like a shoe-lace, the hooks which have been attached to the upper and the lower teeth (Fig. 267). In reducing the fractures these metal hooks are used as points of attachment for intermaxillary elastic bands.[3]

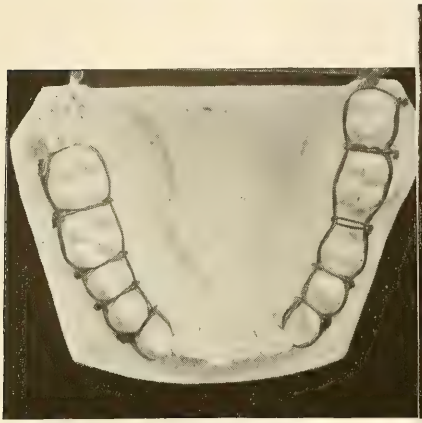

Fig. 225.

Fig. 226.

Figs. 225, 226.—Monomaxillary Ligatures. (After Darcissac.)

Monomaxillary Ligatures.—These are indicated in simple or indirect fractures when both fragments contain teeth. The wire is wrapped twice around a series of teeth on each fragment at the level of the necks of the teeth; then the wires from the lingual side and from the buccal side are fastened together opposite each proximal space with another

Fig. 227.—Angle's Appliances in the Treatment of Fractures. (After Davenport.)

wire, which passes first under and then over the point of contact (Figs. 225, 226, 266).

Metal Bands or Rings—Angle's Arc.—Angle's appliance, which is used in orthodontia, has been of very great service in the treatment of fractures during the war. The apparatus is simple, not cumbersome,

and is easily kept clean. The bands are adjusted on the teeth remaining in the fragments and cemented in place. The arch is then put in position and the teeth ligated one after the other. The appliance is used for reducing fractures, for securing fixation, and for intermaxillary wiring (Fig. 227).

Wedging (Wood, Cork, Vulcanite).—This method is used in the reduction of fractures. A cork is interposed between the teeth of the fragment which is displaced upward and the teeth of the upper arch, in order to allow the fragment which has been displaced downward to resume its normal position by muscular contraction (Case No. 11).

Gutter-splints.—The buccal gutter-splint is the type of intrabuccal appliance. (Splint, Fig. 228.) It is made of vulcanite or of cast or stamped metal. The stamped gutter-splint (German silver No. 36 American gage) is reinforced with a wire which passes around it midway between the cusps and necks of the teeth, and the whole is flooded with solder, with the exception of the free edge of the splint (American

Fig. 228.—Gutter Splint Made Partly of Metal and Partly of Vulcanite, with Guide. (After Darcissac.)

ambulance splint). This apparatus is used for the reduction and fixation of fractures. In fractures of the inferior maxilla it will be found easier to put it in position if the fragments are first rendered movable by massage. If reduction is found difficult, the fragments may be spread apart by interposing a screw forceps and keeping it in position a few seconds. Finally, at the instant of putting the gutter-splint in position, the right and left fragments may be spread with the aid of a wire attached to the teeth, the extremities of which are held taut by an assistant. The gutter-splint is left in place forty-eight hours and is then withdrawn and cemented. If the teeth are too short and the appliance has a tendency to slip, this can be prevented by adding small brads or screws, which fit into the interdental spaces.

Metal gutter-splints that are intended to be cemented in place for some time must never come in contact with the gums, but must be adjusted on the teeth as far as the necks only (Fig. 232). It is often necessary to prepare gutter-splints made partly of metal and partly of

vulcanite when there is considerable loss of substance to be filled in, when fragments that have no teeth are to be held in position (Fig. 228), or a protective apparatus for cheiloplasty* is required (Figs. 255, 289).

Guides or "Wings."—Splints, either of metal or vulcanite, are provided either on the buccal or on the lingual surface with guides or flanges (ailettes) (Fig. 228), or with flanges which slide on each other (glissières) (Fig. 229). These special contrivances are for the purpose of constantly retaining the various fragments in their normal position, or of counteracting inversion of one of the fragments.

Rings with Guides.—In fractures of the lower jaw, when the posterior fragment contains but a single tooth, fixation is obtained by attaching to the remaining tooth a ring with guides, and securing the latter to the splint of the anterior fragment (Fig. 264).

FIG. 229.—METAL SPLINT WITH GUIDE OR FLANGES. (After Darcissac.)

Intrabuccal Appliances with the Point of Support Inside the Mouth, but Exerting Extrabuccal Traction.—These are for the purpose of reducing the fracture. They are made of two gutter-splints with extrabuccal extensions at their anterior portions for the purpose of using elastic bands or springs. They have been used in fractures of the lower and upper jaw (Case No. 3, apparatus of Darcissac).

Appliances Used for Secondary Reduction.—The choice of apparatus depends on the strength of the available points of support and of the force necessary to reduce the fracture.

1. *Jack-screws, Springs, Inclined Planes.*—These appliances, intended for the reduction of one of the fragments or for spreading apart of the two fragments, are composed of one or two hard-rubber or metal plates, or two gutter-splints of the same material, with or without guides

* Literally, "plastic operations on the lips."

(wings). For the reduction of fractures in the anterior portion of the lower jaw the two apparatus of hard rubber are connected at their lingual portions by a spring, a piano wire, or a jack-screw (Fig. 258).

2. *Intermaxillary Force.*—The elastic bands used in orthodontia have their points of support on gutter-splints cemented to the fragments and to the teeth of the opposite jaw. The position of the elastic bands is variable, depending on the relative position of the fragments, while the number of elastic bands will be determined by the degree of resistance (Fig. 230).

Fixation.—1. *With the Mouth Open.*—In the case of bone-grafts or osteosynthesis of the lower jaw it is important, *first,* to make sure of complete fixation of the fragments during and after the operation; *second,* during general anesthesia the mouth must remain partly open, leaving a space of 2 cm. between the dental arches. This is achieved by means of hard-rubber blocks prepared beforehand and adjusted be-

FIG. 230.—INTERMAXILLARY FORCE (ELASTIC BANDS). (After Davenport.)

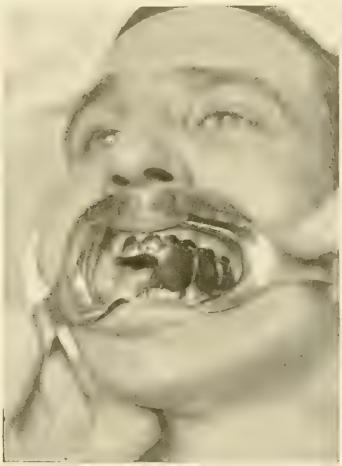

FIG. 231.—FIXATION OF THE MANDIBLE WITH THE MOUTH OPENED. (After Hayes.)

tween the two gutter-splints after the method of Hayes; on one side only if one of the fragments has no teeth at all, but on both sides if both fragments contain teeth. The upper and lower gutter-splints are then united by means of metal ligatures. The hard-rubber blocks are kept in place about three days. The dental arches are placed in occlusion and immobilized in that position (Figs. 231, 232).

2. *With the mouth closed,* that is to say, immobilization of the lower jaw with the teeth in occlusion. Immobilization is called *relative* when the patient is asked to keep his mouth constantly closed or when such immobilization is secured by wearing a rubber bandage or sling. This method must be used in horizontal fractures, so-called Guérin's fractures, of the upper jaw. It may also be used in fractures of the lower jaw when the bony lesions are relatively slight, if the normal interlocking of the dental arches offers a natural means of fixation, and in dealing with young, vigorous, and intelligent subjects. If

this method is used with patients who have lost their teeth a double gutter-splint of hard rubber or an interdental "yoke," which fits perfectly over the alveolar crests or the fragments, must be applied.

Immobilization is said to be *absolute* when the lower jaw is wired or intermaxillary anchorage is used. Such immobilization is obtained

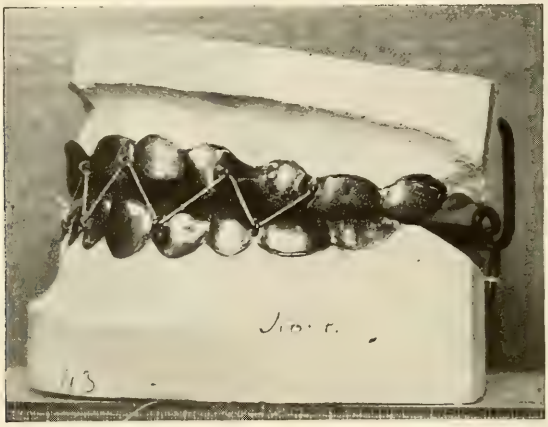

FIG. 232.—FIXATION OF THE MANDIBLE WITH THE MOUTH CLOSED (TEETH IN OCCLUSION).

by means of metal or elastic ligatures directly to the teeth themselves (Figs. 267, 268), to an Angle apparatus, or metal gutter-splints (Fig. 233). The length of time during which immobilization is maintained is variable, depending on the gravity of the bony lesion on which there has

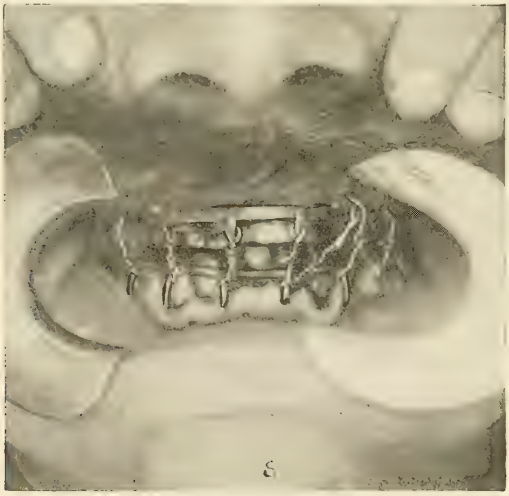

FIG. 233.—FIXATION OF THE MANDIBLE WITH METAL GUTTER-SPLINTS. (After Hayes.)

been any surgical intervention (bone-grafting, osteosynthesis), the age and morale of the patient. Some easily tolerate immobilization for from six weeks to six months (bone-grafting); while in the case of others a forty-eight-hour interval of rest every ten days will be found useful.

This is done by simply removing the metal ligatures or replacing them by elastic ones. Long-continued wiring is contraindicated in the presence of inflammatory lesions of the temporomaxillary articulation. It is the method to be used in all "retrodental" fractures, that is to say, in fractures situated posterior to the dental arch (fracture of the angle and fracture of the ascending ramus); also in those fractures in which one of the fragments is without teeth, or when the points of support are inadequate, as, for example, when a fragment has but a single tooth.

Placing the lower jaw in contact with the upper jaw is absolutely contraindicated in fractures of the upper jaw, in which cases a head-band or the resistance exerted by the skull constitutes the only proper method of fixation; the fragments can be held in good position with hard-rubber plates or metal gutter-splints provided with guides.

HEAVY OR WEIGHTED APPARATUS

These appliances are made of tin, silver, or a combination of metal and vulcanite. They are used for fixation or as permanent appliances

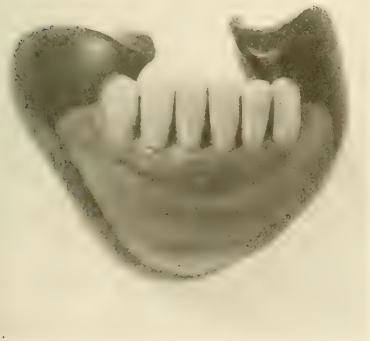

Fig. 234.—Weighted Apparatus Applied in a Case of Very Extensive Loss of the Horizontal Portion of the Mandible. (After Duncombe.)

Fig. 235.—Weighted Apparatus with a Wing in a Case of Very Extensive Loss of the Horizontal Portion of the Mandible, Left Side.

This apparatus is adjusted on the left side on the remaining portion of the ramus. (After Darcissac.)

in fractures of the lower jaw when all the teeth are lost or in case there is very extensive loss of bony tissue in the body of the bone (pseudarthrosis). They are also used for stretching cicatricial tissue (Figs. 234, 235).

PSEUDARTHROSIS

Pseudarthrosis may be regarded as a permanent result after rational treatment has been kept up for six months, that is to say, after complete and prolonged fixation of the fragments in their normal position. The gravity of a pseudarthrosis in the functional sense varies according to its character, *i. e.*, to the mobility of the fragments. This, in turn, depends upon the extent of substance lost and the density of the fibrous tissue which unites the bony extremities. It varies with the site of the lesion. The pseudarthrosis may be symphyseal, lateral, or bilateral. It varies with the number of teeth that remain.

The functional disturbances are comparatively slight in dense or closely approximated pseudarthroses. We have observed exceptions in which, although manipulation failed to reveal any apparent mobility, the patient nevertheless insisted that he was unable to chew solid food. Functional troubles are more marked in symphyseal pseudarthroses and are still more severe in the bilateral variety (Fig. 219).

Relaxed or mobile pseudarthroses are often characterized by extremely grave functional disturbances. Nevertheless, we have seen patients with relaxed unilateral pseudarthroses of the horizontal ramus who were able to maintain the principal fragments in good occlusion and their mastication had become normal.

Treatment.—If mastication is adequate and the functional disability diminishes day by day, there is no occasion to intervene. The

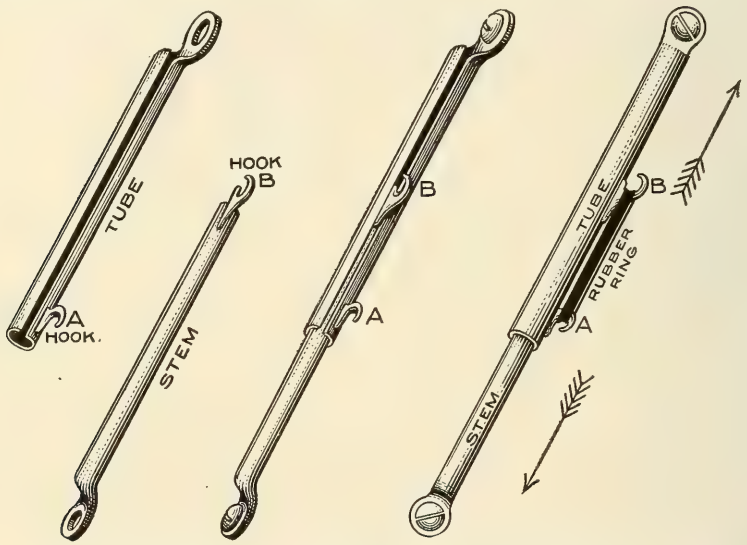

FIG. 236.—TELESCOPING TUBULAR ROD (BIELLE) WITH ITS ELASTIC RING VIEWED FROM BEHIND AND BELOW, SHOWING LONGITUDINAL SLOT IN WHICH THE HOOK OF THE STEM GLIDES. THE LAST FIGURE IS A LATERAL VIEW SHOWING THE ELASTIC RUBBER RING AND THE TELESCOPIC ELONGATION OF THE APPARATUS. (After Morino and Villain.)

patient is taught to re-educate his muscles and is shown the importance of making constant efforts to maintain the principal fragment in its normal position (lateral pseudarthrosis). He is given an apparatus with winglets to wear at night for the purpose of combating muscular relaxation and avoiding change of position of the jaw. Finally, if in spite of our efforts the functional disturbance persists, some form of prosthetic treatment is indicated with or without surgical intervention.

Prosthetic and Surgical Treatment.—Treatment of the pseudarthrosis is exclusively prosthetic when the loss of substance is such that a bony or cartilaginous graft offers little chance of success, or when the gravity of the surgical intervention is such as to constitute a general contraindication. If, on the other hand, the loss of substance is not very extensive, are we obliged to choose between osteosynthesis and an

osteoperiosteal graft? This question is difficult to decide at the present time. I believe, nevertheless, that if the dental surgeon can secure perfect fixation of the fragments he ought to operate if he deems it possible and believes that it offers fairly reasonable chance of success.

The great difficulty in using apparatus in cases of mobile pseudarthrosis lies in the fact that muscular co-operation is entirely lost. The two fragments are unequally elevated and, as soon as the patient increases the contraction of his muscles of mastication, the two fragments deviate according to the pull of the muscles. The teeth of one fragment may be brought in contact with the opposing teeth, while those of the other fragment are kept from contact owing to intervening food.

It is often extremely difficult to maintain the stability of the apparatus. The attempt should never be made to bring about complete immobility of the fragments by means of permanently fixed apparatus.

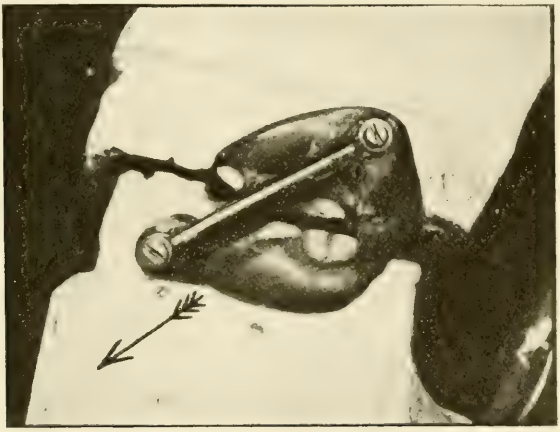

Fig. 237.—Telescoping Tubular Rod (Bielle) in Place, to Show Its Mode of Extension. (After Morino and Villain.)

The use of bridges cemented to the remaining teeth should be avoided, as the latter are unable to withstand such a strain for any length of time. Heavy dentures may prove very useful in such cases. In general, the apparatus should include all the teeth and have a deep hold above the alveolar crests. Inclined planes with flanges (ailettes), placed preferably on the side opposite the pseudarthrosis, may be used in order to enable the patient to masticate on the uninjured side (Fig. 229). Springs and different kinds of piston (bielles) may be utilized. The "bielle" is a device first introduced into orthodontia by Herbst for maintaining the normal relation of the dental arches after distal inferior malocclusions have been corrected.

Telescoping Tubular Rod (Bielle)—Figs. 236, 237.—This is an apparatus attached by bands, gutter-splints, or fixed plates to the upper and lower jaws. It can be lengthened or shortened by means of a bar working in the lumen of the tube. This permits of up-and-down movements of the lower jaw. The articulation of the rod and of the tube

must be free enough to permit of lateral mobility. They are mounted on screws. The rod (bielle) may be passive when the rod is smooth; it becomes active when, instead of a smooth rod, a threaded one is employed. The length of the rod can be increased or diminished at will by means of a nut (George Villain).[4]

The prosthetic treatment of mobile pseudarthrosis still remains a big problem. The dental surgeon will need all his ingenuity if he hopes to reduce in fullest possible measure the functional disability which follows upon this lesion; but, fortunately, functional disability diminishes with time, as the patient becomes accustomed to the new conditions and adapts himself to them. So we may hold out some hope to the gravely mutilated survivors of this terrible war.

INABILITY TO OPEN THE MOUTH—TRISMUS

Wounds affecting the temporomaxillary region and the muscles of mastication are accompanied by more or less severe "trismus" (constriction of the jaws). Trismus may be articular, muscular, or reflex in origin.

Fig. 238.—Mouth-gag with Lever or Screw in the Treatment of Trismus.

The articular form of trismus is very rare in war injuries. As a rule, one has to deal with the muscular type. The injured muscle contracts violently. Contracture follows quickly, but does not last. It yields readily to treatment as soon as the seat of fracture has been disinfected and the fragments fixed in their normal position. If there has been severe inflammation, the muscular tissue undergoes cicatrization and sclerosis, and the contracture becomes permanent. Often the contracture is due to a focus of osteitis in the immediate vicinity, to the presence of splinters of bone, or to a minute foreign body causing irrita-

tion and contraction of the muscle. With muscular contracture there is nearly always lateral deviation of the mandible in opening the mouth. This is not the case with reflex or spasmodic contractures, in which such lateral deviation does not take place on opening the mouth.

Treatment.—The cause of the contracture must be definitely ascertained, a careful search for foreign body, by all means including roentgenographic examination. The treatment should be begun as soon as possible in order to prevent the contracture from becoming permanent. Forced opening of the jaws causing rupture of the tissues must be avoided. Physical methods, such as massage, the application of hot air, and electricity, are indicated. After that the various kinds of mechanical dilators must be employed: wooden blocks, corks, mouth-gags with lever or screw (Fig. 238), Lebedinsky's apparatus, or wooden clothes-pins with springs, such as laundresses use which have been found very useful. Finally, the inclined plane wedge (Valadier), made of a filing block, used in the dental laboratory, 2 inches long by $\frac{3}{4}$ inch in breadth. The blocks are made in four sizes from the thinnest portion to the thickest portion. These wedges are placed between molars and bicuspids and kept continually in place except when eating. Whatever procedure is selected must be employed slowly and methodically, and no attempt made to hurry the treatment. The dilatation is carried out gradually, one séance in the morning and one in the evening; at first very short and gradually prolonged. Between the séances the patient is advised to practice opening his mouth in order to restore the suppleness of the muscles and the mobility of the joint. He can also wear corks between his dental arches so as to maintain the gain that he has made at each séance. Mechanotherapy has always given us the best results.

CASES TREATED IN THE DENTAL DEPARTMENT OF THE AMERICAN AMBULANCE AT NEUILLY, PARIS, FRANCE

Fractures of the Superior Maxilla

Case 1.—J. B. Wounded *April 16, 1917* by a shell fragment. Fracture of the superior maxilla by a penetrating wound of the face. Superior maxilla completely separated horizontally from the skeleton at the level of the base of the nose. Displaced downward *en masse* (Fig. 239). *May 2d:* Impressions taken of the two dental arches, followed by a metal gutter-splint adjusted to all the teeth of the upper arch. This splint (Figs. 240, 241) is provided at its anterior portion with a special appliance made of wires, which pass backward at the level of the labial commissure, parallel with the lower border of the inferior maxilla, right and left, as far as the ear. These wires have at their upper portion three metal hooks to which are attached rubber bands, and these, in turn, are attached to a skull cap. *May 8th:* Reduction and fixation appliance put in place. The apparatus annoys him but little and permits him to eat easily. This apparatus was worn continuously until *July 30, 1917*. (Author's case.)

Fig. 239.

Fig. 240.

Fig. 241.

Fig. 239.—Mutilation of the Upper Portion of the Face.
Displacement downward *en masse* of the superior maxilla. (After Darcissac.)

Fig. 240.—Splints in Place Showing the Reduction and the Fixation of the Superior Maxilla: Frontal View. (After Darcissac.)

Fig. 241.—Splints in Place Showing the Reduction and the Fixation of the Superior Maxilla: Lateral View. (After Darcissac.)

Case 2.—I. L. Wounded *September 28, 1915* by a shell fragment. Fracture of the maxilla by penetrating wound of the face. The superior

FIG. 242.—FRACTURE OF THE SUPERIOR MAXILLA.
Photo showing displacement downward, forward, and toward the right. Mutilation of the superior portion of the face. (After Hayes and Darcissac.)

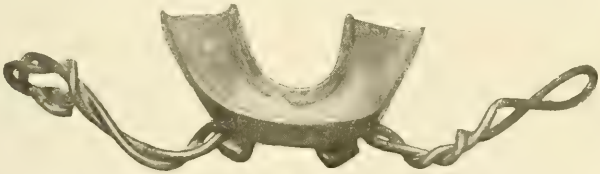

FIG. 243.—TEMPORARY SUPPORTING APPARATUS. (After Hayes and Davenport.)

FIG. 244.—PERMANENT METAL SPLINT FOR THE REDUCTION AND THE FIXATION OF THE SUPERIOR MAXILLA. (After Darcissac.)

maxilla was completely separated from the skeleton horizontally at the level of the base of the nose. Displacement downward, forward,

and to the right (Fig. 242). *October 5th:* A supporting apparatus (Fig. 243) made on a mold with two lateral extensions was put in place (Hayes and Davenport). On the same day an impression was taken

FIG. 245.—SPLINT IN PLACE IMMOBILIZED BY MEANS OF FOUR TAPES TIED TOGETHER ON THE TOP OF THE HEAD. (After Darcissac.)

of the superior dental arch, and a metal gutter-splint covering the teeth and part of the palatal vault was applied (Fig. 244). The splint is provided with two lateral extensions which pass backward at the level of the labial commissure, parallel with the inferior border of the lower

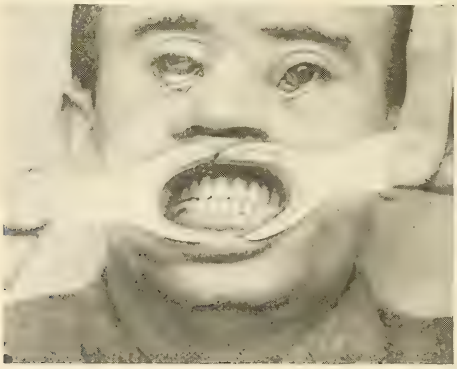

FIG. 246.—PHOTO SHOWING THE TREATMENT FINISHED AND THE TWO PERMANENT DENTURES IN PLACE. (After Darcissac.)

jaw. The right branch has an extension terminating in a small supporting wing. The appliance is immobilized by means of four tapes tied together on the top of the head (Figs. 245, 246). (Author's case.)

Case 3.—Fracture of the superior maxilla with loss of substance

and posterior displacement of entire anterior portion. F. E., age twenty-five years, wounded *October 6, 1915.* Admitted *January 28, 1916.* Wounded by a shell fragment which entered near the lower

FIG. 247.—FRACTURE OF THE SUPERIOR MAXILLA; THE INCISOR PORTION IS VERY MOBILE AND MARKEDLY DISPLACED BACKWARD. (After Darcissac.)

eyelid and emerged on the right cheek 2 cm. behind the ala of the nose. Enucleation of the left eye. Fracture of the nasal bones. Fracture of the superior maxilla and abrasion of the vault of the palate. Loss of

FIG. 248.

FIG. 249.

FIGS. 248, 249.—METAL SPLINTS IN PLACE FOR REDUCTION OF A FRACTURE OF THE SUPERIOR MAXILLA. (After Darcissac.)

all the molars and premolars of the upper jaw on both sides. *Condition on admission:* The wounds of the face are cicatrized. The nose, the upper lip, and the entire intermediate portion of the face are sunken

in *en masse*. The incisive portion is very mobile and markedly displaced backward (Fig. 247). Pseudarthrosis along a line corresponding to the right and left premolars. The incisor mass comprises two left lateral incisors, the right canine, and the second left molar. There is also a fissured fracture of the vault of the palate. The inferior dental arch is intact.

Treatment: On *March 4, 1916* two metal gutter-splints, stamped and reinforced, were prepared. The splint for the lower jaw covered all the teeth; that of the upper jaw encircles the four remaining teeth and the entire incisive portion (anterior portion of the palatine vault and the alveolar process). Near the labial commissure each splint is provided with two metal rods parallel in every plane; these rods are bent upward at a right angle, to the right and left of the alæ of the

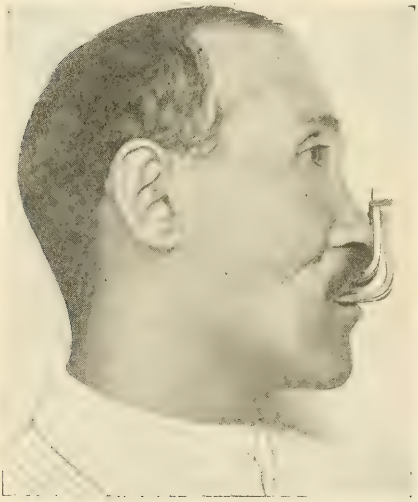

FIG. 250.—SAME CASE SHOWING THE RESULT OBTAINED. (After Darcissac.)

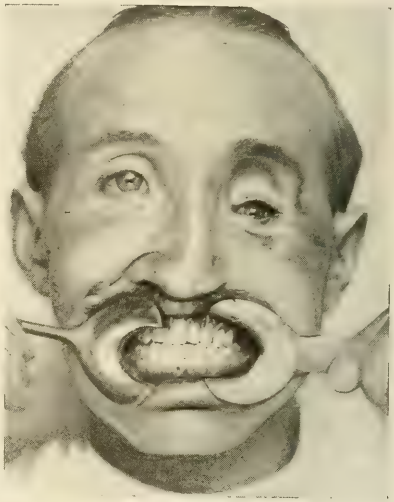

FIG. 251.—PHOTO SHOWING THE PROSTHETIC DENTAL APPLIANCE IN PLACE. (After Darcissac.)

nose. The two rods attached to the lower splint project 4 cm. in front of the rods attached to the upper splint. The vertical portions, about 5 cm. high, act as guides (Figs. 248, 249).

The object of treatment is to bring the entire facial massif forward, from the base of the nose to the incisor teeth. Four nuts are placed on the inferior portion of the guide and two on the upper portion, so as to bring the two rods attached to the upper splint forward without disturbing their parallelism. On *March 12th* the nuts were replaced by elastic bands which maintained a constant but gentler pressure. On *March 25th* the two vertical rods were found to be in contact (Fig. 250). A marked improvement in the esthetic sense was noticeable; the incisors were in normal occlusion. This result was maintained for a month and a half and then the splints were removed. Impressions were taken and a prosthetic dental appliance was immediately put in

place, its object being to take the place of the missing teeth and to maintain the anterior portion of the upper jaw in its normal position (Fig. 251).[5] (Author's case.)

Fracture of the Superior and Inferior Maxillæ

Case 4.—P., age twenty-seven. Wounded *September 26, 1916.* Symphyseal fracture of the inferior maxilla. Fracture of the tuberosity

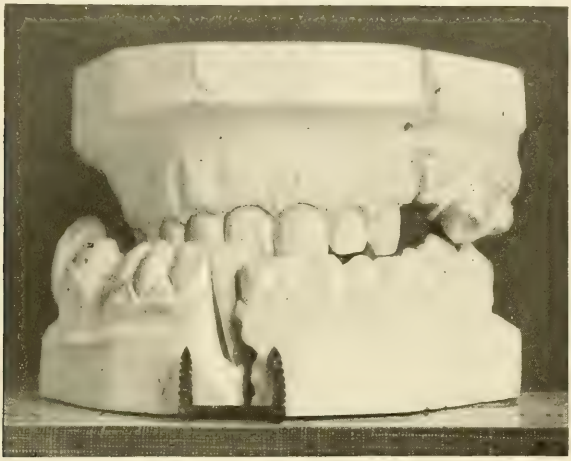

Fig. 252.—Fracture of the Superior Maxilla. (After Davenport.)

of the superior maxilla and of the left palatine arch anteroposteriorly. Figure 252 shows the displacement of the fragments. Reduction of the fracture of the inferior maxilla was obtained by torsion of a wire (Fig. 253), and fixation is assured by a metal gutter-splint cemented to the

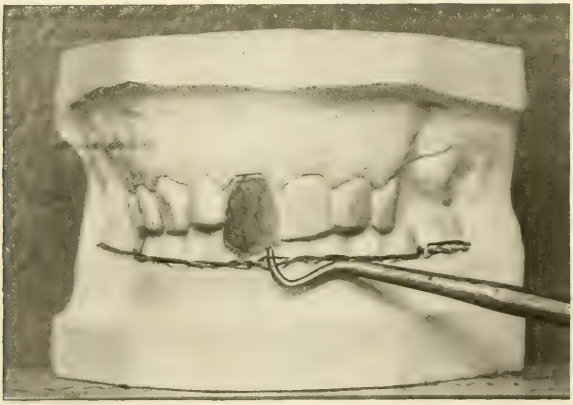

Fig. 253.—The Reduction of the Fracture of the Mandible was Obtained by Torsion of a Wire. In the superior maxilla an inclined plane cemented to the teeth serves to reduce the fracture and maintain fixation. (After Davenport.)

fragments. In the superior maxilla an inclined plane cemented to the teeth serves to reduce the fracture and maintain fixation. (Davenport's case.)

Fracture of the Mandible

(*a*) **Fracture of the Anterior Portion.—Primary Reduction. Case 5.**—P. C., age thirty-four. Wounded *May 18, 1916* by shell fragment. Mutilation of the lower portion of the face; penetrating wounds of the lips and chin, with loss of substance. Comminuted fracture of the anterior portion of the inferior maxilla. Fracture of the

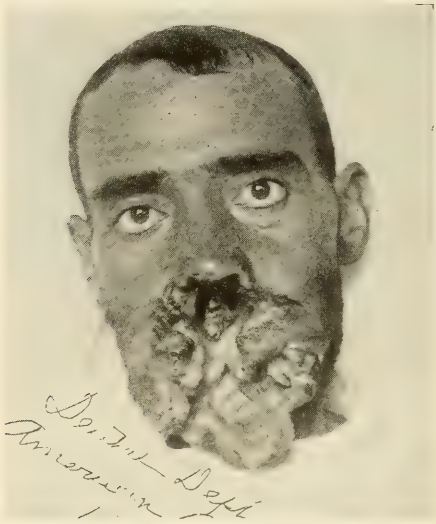

Fig. 254.—Fracture of the Mandible.
Mutilation of the lower portion of the face. (After Darcissac.)

anterior portion of the superior maxilla. Displacement of the right and left fragments of the inferior maxilla toward the median line.

Treatment begun *June 19, 1916.* Severe infection of the mouth; antiseptic irrigations every two hours. The tongue was cleansed and much tartar removed from the teeth. All free and denuded splinters

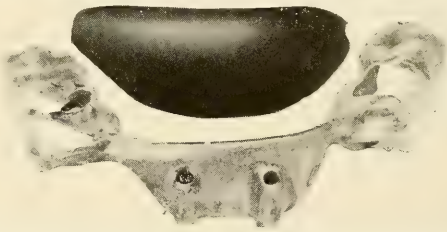

Fig. 255.—Metallic Gutter-splint for Fracture of the Anterior Portion of the Mandible.
Its anterior portion carries a removable piece of vulcanite. (After Darcissac.)

of bone were removed. The upper lip, which had been divided in the median line, was sutured. The tissues in the mental region, which were badly lacerated, were brought together and fixed with several sutures in order to prevent cicatricial contraction, which would make any plastic procedures more difficult in the future (Fig. 254). *June 26th* impressions were taken of the right and left fragments of the mandible, and a metallic

gutter-splint was applied for the purpose of immobilizing the fragments in their normal position. It would undoubtedly have been better and less painful to the patient had this fixation apparatus been applied before the surgical procedures. The metallic gutter-splint covered the remaining teeth on both sides; at its anterior portion it is provided with two parallel vertical tubes through which pass two metal rods, which carry a removable piece of vulcanite (Fig. 255, protective apparatus for cheiloplasty).

October 2d: Broken teeth were extracted and a plastic operation performed on the lower lip. *December 18th* the lower gutter-splint was removed and the immovable vulcanite piece replaced by a small plate with eight porcelain teeth. It was noted at this time that the bony defect in the anterior portion of the inferior maxilla was in part filled in by osteocartilaginous callus, and it seemed certain that this bony lesion, which appeared to be so severe, would finally heal completely. *December 22d:* An appliance of vulcanite with eight teeth was applied to the superior maxilla. On account of atresia of the buccal orifice and the presence of cicatricial bands it was extremely difficult to introduce the mold into the mouth and take the impression.

FIG. 256.—CASE FINISHED.
Photo showing the vulcanite plate on the lower jaw. (After Darcissac.)

May 10, 1917: The patient is wearing a small appliance, the object of which is to counteract the atresia of the buccal orifice. It consisted of two half-gutters of vulcanite which fitted into the labial commissure and were attached to each other by a metal spring (Figs. 291, 292). *May 16th:* An impression of the inferior maxilla was taken. *May 21st:* A vulcanite plate with seven teeth was applied to the lower jaw, the object being to restore the continuity of the dental arch and to fill in the loss of bony substance in the anterior and the superior portions of the lower jaw (Fig. 256). Treatment terminated *May 25, 1917.* (Author's case.)

Case 6.—Fracture of the anterior portion of the mandible with loss of substance.

J. G., wounded *September 13, 1914* by a rifle bullet at 30 meters. Admitted *September 29th.* Large penetrating wound of the chin with loss of soft tissues and partial removal of the anterior portion of the mandibular arch. The two fragments of the jaw are mobile and have a tendency to become displaced toward the median line. *Treatment:* Careful cleansing of the mouth and teeth. Antiseptic irrigation with

weak solutions of iodin and zinc sulphate. The saliva flowed continually into a rubber bag below the chin. Every kind of submental dressing was dispensed with. A metallic gutter-splint was prepared consisting of three bands applied to the remaining teeth on each side and reinforced by a wire uniting the right and left parts of the splint. To the anterior portion of this wire were attached three porcelain teeth. The gutter-splint was cemented in place *January 16, 1915* (Fig. 257). *March 23, 1915* a plastic operation was done on the lower lip. *September 29, 1915* bone-grafting of the anterior portion of the inferior maxilla. *February 21, 1916* prosthetic apparatus applied. (Hayes' case.)

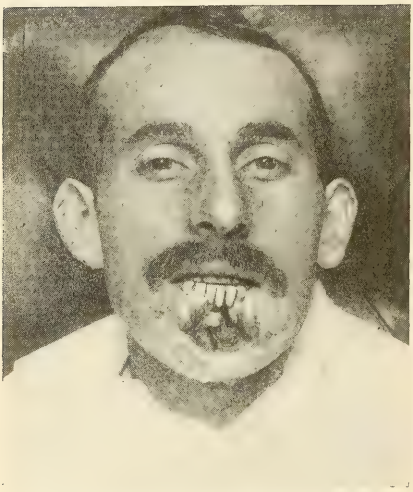

FIG. 257.—METALLIC GUTTER-SPLINT WITH ARTIFICIAL TEETH FOR FRACTURE OF THE ANTERIOR PORTION OF THE MANDIBLE. (After Hayes.)

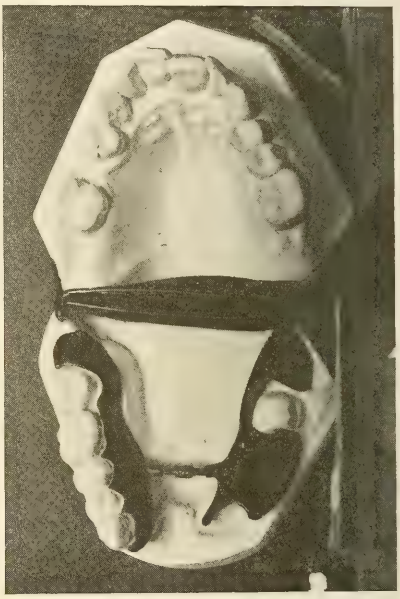

FIG. 258.—VULCANITE APPARATUS FOR SECONDARY REDUCTION OF A FRACTURE OF THE ANTERIOR PORTION OF THE MANDIBLE. (After Darcissac.)

Secondary Reduction. Case 7.—L. G. Comminuted fracture of the anterior portion of the mandible. Wounded *May 11, 1915* by a rifle ball. On admission, *June 19th,* the right and left fragments of the maxilla were displaced toward the median line, bringing the two canines in contact. The fragments were slightly movable. Reduction of the fracture impossible. *June 21st* the teeth were cleansed, carious teeth filled, and the fractured ones extracted. Impressions were then taken. *June 29th* a vulcanite apparatus (Fig. 258) was put in place. The right and left sides of this appliance were united by a screw rod (vis de jack) for the purpose of separating the fragments and reducing the fracture. *July 15th:* Reduction is complete. At this time the left canine and premolar, which were entirely dislocated, were extracted; also a few infected roots.

July 20th: Application of a metal gutter-splint (Fig. 259) with two

guides, one on the buccal surface of the right half and the other on the lingual surface of the ring attached to the second left molar. This latter guide had its point of support on the alveolar margin. Wounds cicatrized. *August 4th:* The gutter-splint was cemented.

September 13th: Articulation was normal and the gutter-splint was removed. The right fragment still exhibited slight lateral mobility. The gutter-splint was replaced without cement. *September 18th:* Great improvement. The fracture is progressing toward consolidation. Impressions taken and prosthetic appliance applied. (Author's case.)

Tardy Reduction. Case 8.—E. B., forty-two years old, wounded *February 24, 1915* by a rifle bullet. Admitted *April 19, 1915.* Fracture of the body of the mandible. Total loss of about 4 cm. of the entire anterior portion and of all the teeth, from the first right large

FIG. 259.—METAL GUTTER-SPLINT FOR THE SAME CASE FOR FIXATION OF THE FRAGMENTS AFTER THE REDUCTION OF THE FRACTURE. (After Darcissac.)

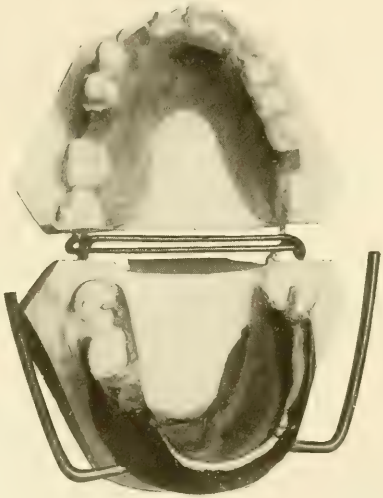

FIG. 260.—VULCANITE APPARATUS FOR FIXATION OF A FRACTURE OF THE ANTERIOR PORTION OF THE MANDIBLE WITH LOSS OF SUBSTANCE AND ALL THE TEETH. (After Darcissac.)

molar to the opposite second large molar. On admission, pseudarthrosis of the mandible with great mobility. Fragments in lingoversion and displaced toward the median line. The left fragment has but one tooth; the right fragment two. Impressions taken and fracture immediately reduced on the cast. Vulcanite apparatus prepared covering the two fragments and surrounding the remaining teeth. It has two metal rods which reach to the labial commissure and are bent backward parallel with the lower border of the jaw (Kingsley's apparatus, Fig. 260).

June 28th: Section of fibrous ligament by the surgeon under general anesthesia. Immediate reduction of the fracture. Application of the fixation apparatus, immobilization being obtained by a bandage under the chin. *July 8th:* The stability of the appliance is such as to justify removal of the two metal rods. *July 31st:* Apparatus replaced by

another heavy one of tin, with a deeper hold on the two fragments. (Author's case.)

(*b*) **Fracture of the Horizontal Portion of the Mandible. —Primary Reduction. Case 9.**—P. B., age twenty, wounded *May 12, 1915* by a rifle bullet. Comminuted fracture of the horizontal portion of the left inferior maxilla. On admission the fragments were movable. The left fragment was displaced toward the median line (Fig. 261). *Treatment: May 29th* the teeth were cleansed and the fractured ones extracted. *June 3d:* Impressions were taken and the fracture reduced on the plaster models; the cast was cut at the level of the left lower canine. *June 10th:* A metallic gutter-splint applied (Fig. 262). The splint was perforated at the points of contact in order to obtain better articulation of the dental arches. As reduction of the fracture was difficult, massage was first employed and a screw forceps inserted between the fragments to spread them apart and render it easier to apply the gutter-splint at once. The latter was not cemented until a

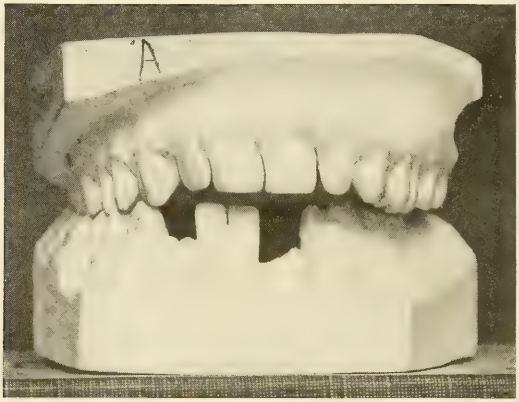

FIG. 261.—COMMINUTED FRACTURE OF THE HORIZONTAL PORTION OF THE LEFT INFERIOR MAXILLA. Photo showing the displacement of the fragments.

few days later. *July 31st:* Gutter-splint removed. Slight mobility of the fragments; fracture in a fair way toward consolidation. The fixation apparatus was put back for a few weeks longer. (Author's case.)

Coaptation of Fragments. Case 10.—P. S., nineteen years old. Wounded *February 26, 1917* by fall in an airplane. Open fracture of the horizontal portion of the mandible, right side. *May 29th:* Present condition: Patient wears a fixation gutter-splint of metal cemented to the teeth of the lower arch. Fistulous tracts at the seat of fracture on the buccal and the external sides. Pseudarthrosis of the horizontal portion of the right maxilla at the level of the first large molar.

Treatment begun *June 5, 1917.* Extraction of the second premolar on the right side, which is in direct relation with the seat of fracture. *June 11th:* Application of two metal gutter-splints, one of which is applied to the posterior right fragment and the other to the left fragment. These two splints have on their outer surface small metal hooks for the attachment later on of elastic bands or of metal ligatures. The

splint applied to the left fragment is provided with a metal guide. In the upper jaw small metal hooks are placed on the front teeth at the level of the necks.

June 12th: Fixation of the mandible. The gutter-splint cemented on the right posterior fragment of the inferior maxilla was united with the anterior gutter-splint by elastic bands in order to draw the posterior fragment forward and obtain better coaptation of the fragments. *June 18th:* Fixation of the inferior maxilla with metal ligatures. The elastic bands applied for drawing the posterior fragment forward were replaced by wires. Traction is exerted by twisting these wires on themselves. The second molar of the right lower jaw, being infected, was extracted, and a simple metal ring cemented

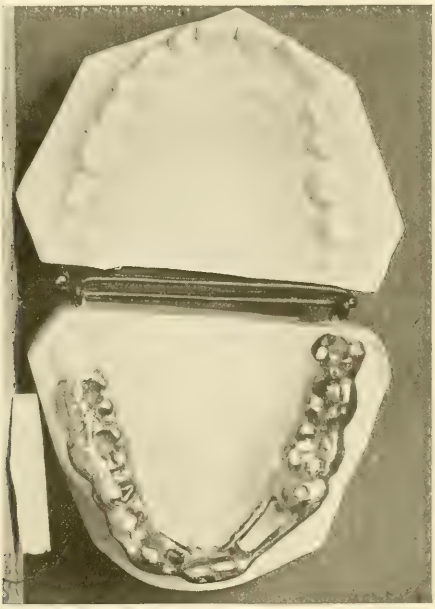

FIG. 262.—METALLIC GUTTER-SPLINT APPLIED AFTER REDUCTION FOR FIXATION OF THE FRAGMENTS. (After Darcissac.)

to the third molar of the same side. The forward displacement of the posterior fragment was progressing favorably, and the fracture seemed to be on the road to consolidation. The two fractured upper central incisors were replaced by two porcelain crowns. *October 15th:* Metal gutter-splints removed; articulation was absolutely normal, and the fracture entirely consolidated. *October 30th:* Treatment completely terminated. The missing teeth on the inferior maxilla were replaced by a small prosthetic appliance. (Author's case.)

Secondary Reduction. Case 11.—E. G., age thirty-three, wounded *June 8, 1915* by a shell fragment. Comminuted fracture of the horizontal portion of the right lower maxilla. Treatment begun *June 21, 1915.* Photographs, impressions, and cleansing of the teeth. The anterior fragment was displaced to the right and downward. There is an in-

terval of 4 mm. between the upper and lower front teeth. The fracture cannot be reduced (Fig. 263). *June 29th:* Extraction of a small sequestrum. Surgical intervention in order to reduce the fracture. Impressions taken and the fracture reduced on the model. The patient wore constantly, day and night, a cork interposed between the posterior fragment and the upper arch (Claude Martin's method), so as to permit the anterior fragment to move upward. The gutter-splint was put in place *July 1st.* Before this operation a screw spreader had been interposed between the two fragments in order to obtain the necessary space. The gutter-splint was put in place and remained in position. The patient continued to wear a cork between the gutter-splint, which was not cemented, and the upper arch (Fig. 264).

End of July the anterior fragment was in perfect occlusion, the patient could remove the gutter-splint himself and put it back again when he brushed his teeth. *End of August:* Fracture completely con-

FIG. 263.—PHOTO SHOWING THE DISPLACEMENT OF THE FRAGMENT IN A FRACTURE OF THE HORIZONTAL PORTION OF THE MANDIBLE, RIGHT SIDE. (After Darcissac.)

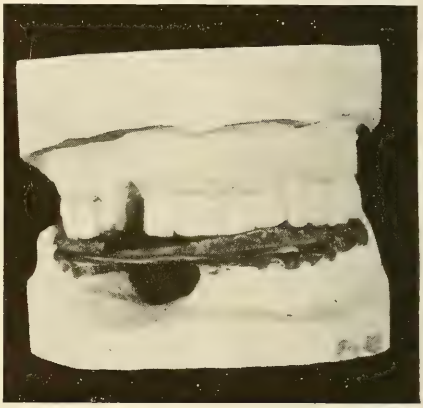

FIG. 264.—METALLIC GUTTER-SPLINT IN PLACE FOR FIXATION OF THE FRAGMENTS. (After Darcissac.)

solidated. *September 6th:* A prosthetic appliance of three teeth was inserted to take the place of the fractured teeth and counteract any possible displacement of the fragments. A salivary fistula was completely cured by placing him on an absolutely milk diet for three weeks.

The treatment was completely terminated *September 15th* (Fig. 265). (Author's case.)

Case 12.—A. D., age twenty-one, wounded *June 10, 1916* by a shell fragment. Comminuted fracture of the inferior maxilla at the level of the right lateral incisor.

Treatment begun *June 21, 1916.* The left fragment was displaced downward, the right fragment toward the right. There was an interval of about 5 mm. between the two. The patient wore a cork interposed between the upper and the lower teeth on the right side in order to force the right fragment downward and permit the left fragment to come into normal occlusion.

Fracture reduced *June 25th.* The two fragments were immobilized and held in their normal positions by means of a metal ligature which surrounded the distal aspect of the left first premolar and, on the right, the distal aspect of the canine. The wires of the lingual side and those of the labial side were united at the level of each proximal space by small metal ligatures (Fig. 266). The fixation thus obtained was perfect and reduction permanent.

September 8th: The metal ligatures were removed. Union of the fragments was perfect and the fracture appeared to be entirely consolidated. Mastication of solid food was still difficult.

February 17th: Recovery is complete and alimentation absolutely normal. (Author's case.)

Case 13.—E. C., twenty-five years of age. Comminuted fracture of the horizontal portion of the right lower maxilla. Wounded by the explosion of a hand-grenade *March 31, 1916;* admitted *April 3d.* He

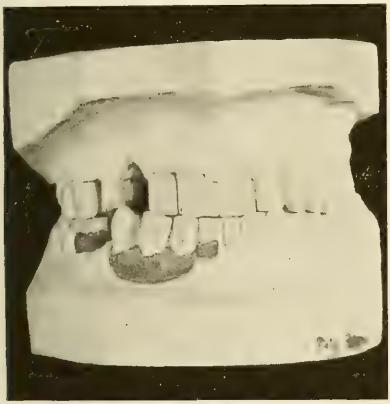

FIG. 265.—CASE FINISHED.
Photo showing the perfect articulation of the teeth and the artificial teeth in place. (After Darcissac.)

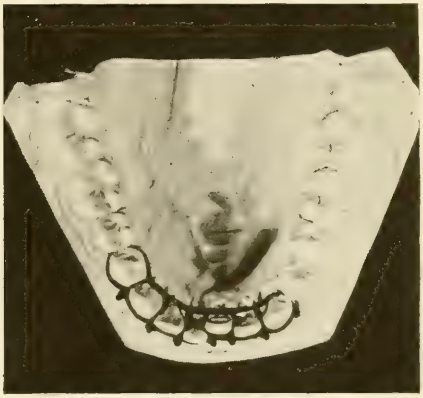

FIG. 266.—COMMINUTED FRACTURE OF THE MANDIBLE.
The two fragments were immobilized by means of a metal ligature. (After Darcissac.)

had a large gangrenous wound of the right cheek. The posterior fragment was slightly displaced toward the buccal side and still carried the second large molar. The anterior fragment was movable and drawn toward the site of fracture. The first molar was fractured and the two small molars dislocated. All the other teeth were present. The dental arch of the superior maxilla was intact.

Reduction of the posterior fragment begun *April 18th* by means of intermaxillary elastic bands attached to two small metal ligatures, one at the neck of the lingual surface of the first right lower molar and the other at the neck of the buccal surface of the first upper right molar. Reduction was obtained in four days.

April 25th: The inferior maxilla is maintained in normal occlusion by means of intermaxillary metal ligatures (Fig. 267). The first molar, being mobile, was extracted in order to facilitate the anterior displacement of the posterior fragment and hasten the formation of a

bony callus. The patient wore a rubber bandage. *May 30th:* Ligatures removed. The fracture is in process of consolidation. The treatment is terminated *September 14th.* Consolidation is complete. (Author's case.)

(*c*) **Fracture of the Angle of the Inferior Maxilla.—Primary Reduction. Case 14.**—E. V., age thirty-seven, wounded *August 17, 1916* by a shell fragment. Comminuted fracture of the angle of the left inferior maxilla. Admitted *August 24th.* There was deviation of the principal fragment toward the left. Treatment was begun *August 29, 1916.* The second and third molars, near the seat of fracture, were extracted. *September 4th* metal ligatures applied and the inferior maxilla immoblized until *October 4th* (Fig. 268). The patient was relieved of his dressing for twenty-four hours and the maxilla again

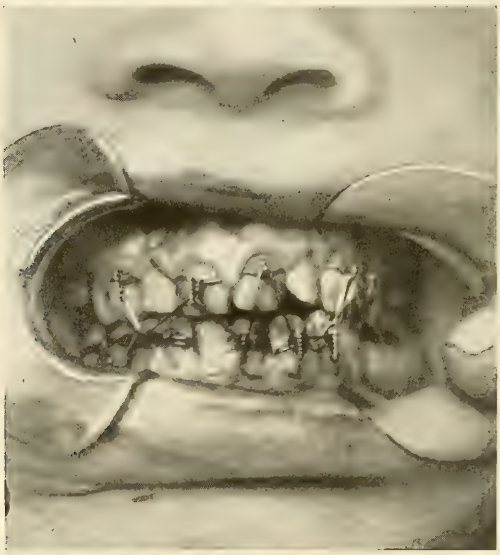

FIG. 267.—COMMINUTED FRACTURE OF THE HORIZONTAL PORTION OF THE RIGHT LOWER MAXILLA. The reduction and the fixation were obtained by means of intermaxillary elastic bands and intermaxillary metal ligatures. (After Darcissac.)

immobilized until *October 15th. October 17th:* Curetment of the maxillary sinus. At this time the fracture appeared to be consolidated; the opening of the mouth was very limited.

November 21st: Treatment begun to combat trismus. First the patient was instructed to use the forceps for progressive separation of the jaws. Later, blocks of wood, which at first he wore for two hours a day, then for increasingly longer periods, until finally he kept them in place all day long. *January 24, 1917* the space between the dental arches is normal; mastication of food is perfect on the right side, but still difficult on the left. (Author's case.)

Case 15.—H. M. H. Marcel, age twenty-two. Comminuted fracture of the angle of the left inferior maxilla. Wounded *September 15, 1915* by a rifle bullet in the right cheek, causing fracture of all the upper and

lower molars on the right side and complete fracture of the body of the inferior maxilla near the angle. Admitted *October 21, 1915.* The principal fragment deviated toward the left. Immediate reduction of the fracture was found possible, although difficult. The mouth could only be opened to a very limited extent (Fig. 269). The superior maxilla contained the first right premolar and all the front teeth; on the left side, the first premolar and the first molar. The inferior maxilla retained all the front teeth and the two premolars on the left side.

Treatment began *October 21st.* On account of trismus it was impossible to extract the fractured teeth or to take impressions. *October 23d:* Extraction of numerous free splinters in the oral cavity. Metal ligatures placed on all the front teeth including the canines, forming six small hooks attached to the upper teeth and six to the lower teeth. *October 27th:* The principal fragment was brought into normal occlusion

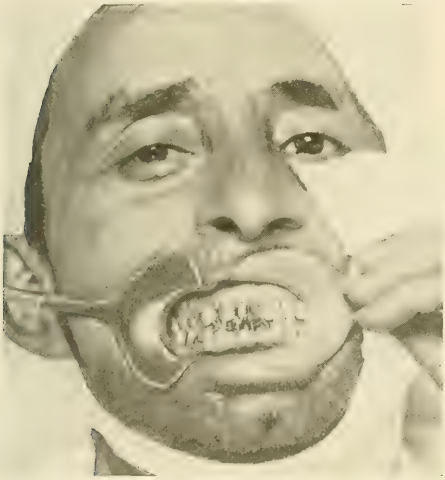

FIG. 268.—FRACTURE OF THE ANGLE OF THE MANDIBLE. Metal ligatures showing the fixation of the mandible. (After Darcissac.)

FIG. 269.—COMMINUTED FRACTURE OF THE ANGLE OF THE MANDIBLE, LEFT SIDE. The principal fragment deviated toward the left. (After Darcissac.)

and retained by means of a wire which passed like a lacing alternately over the hooks attached to the upper and those attached to the lower teeth. In this case, owing to the difficulty of immediate reduction and, consequently, of fixation, an exception was made, and the canines and first premolar in the left inferior maxilla were united by means of two wires of large caliber to the canine and first premolar of the superior right maxilla. A rubber bandage was applied. Every ten days or so the intermaxillary wires were removed for twenty-four hours. The patient was thus enabled to rest, and the normal play of the temporomaxillary articulation possibly stimulated the formation of bony callus.

December 20th (fifty days later) the intermaxillary ligatures were removed, and the fracture found in a fair way toward consolidation. Irrigation of the fistulous tract which communicated with the seat of fracture was continued.

February 9th: Fistula closed. All the fractured teeth were extracted. The patient used the screw spreader to counteract the slight contraction of the muscles of mastication. Treatment is terminated *April 10th* by the application of two prosthetic appliances. Consolidation complete. (Author's case.)

Secondary Reduction. Case 16.—A. M. Irreducible fracture of the angle of the right inferior maxilla. Deviation of the principal fragment toward the seat of fracture and mobility of the said fragment (Fig. 270). Treatment begun *April 28, 1915.* Models and photographs taken; teeth cleansed and diseased teeth filled. Reduction of the fracture impossible. *May 8th* an inclined plane of vulcanite was put in place. Lateral displacement of the inferior fragment was thus gradually obtained. Toward the *end of May* the two left dental arches

FIG. 270.—UNREDUCED FRACTURE OF THE ANGLE OF THE RIGHT INFERIOR MAXILLA.
Deviation of the principal fragment toward the seat of fracture.

FIG. 271.—CASE 16 FINISHED, SHOWING THE PERFECT ARTICULATION OF THE TEETH. (After Darcissac.)

were on the same plane. At this time the two second molars only were in contact and in mesial occlusion as regards the upper molars. This fragment protruded, leaving a space of about 3 mm. between the incisors.

June 17th: Two stamped, grooved, metallic gutter-splints covering the two left dental arches were applied. Beginning with two intermaxillary elastic bands, the patient was gradually enabled to tolerate six or seven of these bands. *June 29th:* The two median lines correspond. There was a slight interval between the incisors. In order to obtain better occlusion a cork was interposed between the molars for the purpose of forcing the principal fragment downward.

July 10th: The process of overcoming trismus was begun with the screw spreader and corks, especially on the right side, where there is a dense cicatricial band. This procedure is supplemented by internal and

external massage. *July 22d:* Marked improvement; mouth opened much more easily. There was a salivary fistula which yielded to the treatment of milk diet. *August 10th:* Gutter-splints removed, treatment being entirely terminated (Fig. 271). (Author's case.)

Case 17.—Secondary reduction of a fracture at the angle of the inferior maxilla was obtained by the use of the two following methods: First case: The posterior fragment, which was displaced forward and upward and was in intimate contact with the upper wisdom tooth, interfered with the reduction of the principal fragment. After extracting the tooth the principal fragment was successfully brought into normal occlusion and retained there until complete union of the fracture had taken place.

Second case: The posterior fragment, displaced upward and outward, interferes with immediate reduction of the principal fragment. The latter was brought into normal occlusion and retained by means of intermaxillary elastic bands, while the posterior fragment was forced downward by the patient by pressure with his finger. Reduction was obtained in forty-eight hours.

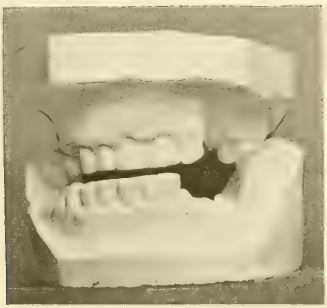

FIG. 272.—PHOTO SHOWING THE DISPLACEMENT OF THE FRAGMENTS IN A COMMINUTED FRACTURE OF THE RIGHT AND LEFT HORIZONTAL PORTIONS OF THE MANDIBLE. (After Darcissac.)

(*d*) **Bilateral Fractures of the Mandible.—Primary Reduction.**

Case 18.—P. M., age forty-two, wounded by a shell fragment *April 22, 1915.* Comminuted fracture of the right and left horizontal portions of the mandible. Condition on admission: The median fragment was movable and displaced downward and forward. The posterior fragment on the right side was displaced outward (Fig. 272).

Treatment begun *May 18th.* Three fractured teeth and six roots extracted and two carious teeth treated. Teeth prepared and an impression taken for a metallic gutter-splint. Owing to the absence of a large number of teeth from the superior maxilla, and the impossibility of reducing the fracture on the model, the three parts of which the gutter-splint is composed were put in place and a plaster impression taken. The fracture was reduced in the mouth, the anterior fragment being held in its normal position during the operation (Figs. 273, 274). The gutter-splint was cemented *May 26th.*

By *June 15th* several small sequestra had come away, and the fistula which was present at the level of the posterior fragment on the

left side had disappeared. The gutter-splint was removed *August 2d.* The fracture was completely consolidated. Impressions were taken and two prosthetic appliances inserted on *August 12th.*

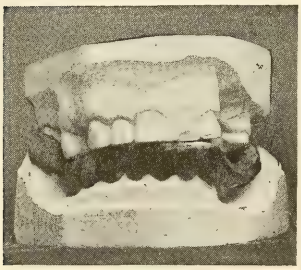

FIG. 273.

FIG. 274.

FIGS. 273, 274.—METAL GUTTER-SPLINT IN PLACE FOR THE FIXATION OF THE FRAGMENT IN NORMAL POSITION. (After Darcissac.)

August 19th: Treatment completely terminated (Fig. 275). (Author's case.)

Case 19.—M. B., age twenty, wounded (rifle bullet) *May 14, 1915.* Penetrating wound of the face; comminuted fracture of the horizontal portions of the right and left mandible.

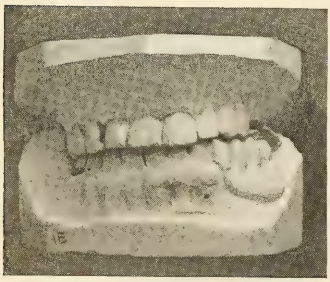

FIG. 275.—TREATMENT COMPLETED.
Photo showing the perfect articulation of the teeth with the artificial teeth in place. (After Darcissac.)

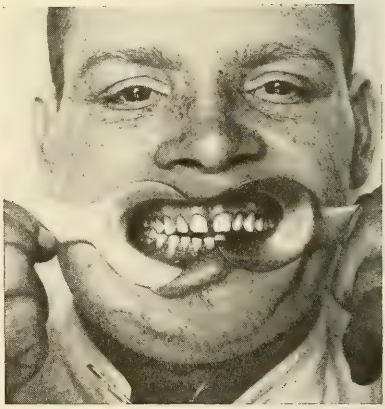

FIG. 276.—COMMINUTED FRACTURE OF THE HORIZONTAL PORTIONS OF THE RIGHT AND LEFT INFERIOR MAXILLA.
Photo showing the displacement of the median fragment.

Treatment begun *June 21st.* Photographs and models taken; teeth cleansed. The median fragment was markedly displaced downward and backward. There is an interval of 1 cm. between the upper and lower incisors. Fracture irreducible (Fig. 276). *June 22d:* Bony splinters extracted and massage instituted for the purpose of mobiliz-

ing the fragments. The two posterior fragments were tilted toward the tongue; the molars are no longer in occlusion with their opposing teeth.

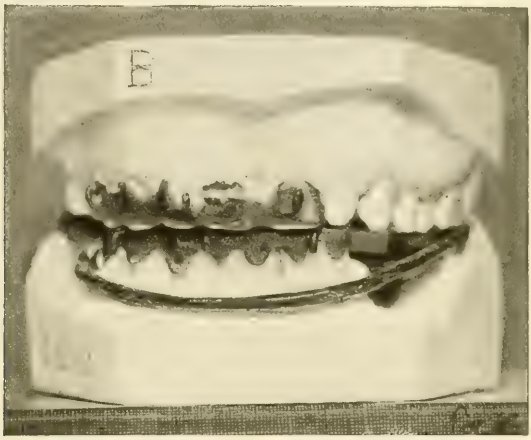

FIG. 277.—GUTTER-SPLINT IN PLACE FOR THE REDUCTION OF THE FRACTURE IN CASE 19. (After Darcissac.)

July 2d: Reduction of the posterior fragment was effected by rings attached to the teeth and a spring adjusted to their buccal surface

FIG. 278.—GUTTER-SPLINT IN PLACE FOR THE REDUCTION OF THE FRACTURE IN CASE 19. (After Darcissac.)

(Fig. 277). Then two gutter-splints were applied: one was attached to the upper incisors and the other to all the teeth of the median fragment, to which hooks were soldered (Fig. 278). The median frag-

ment was gradually brought back to a normal position: 1, by means of intermaxillary elastic bands; 2, by means of metal ligatures through absolute immobilization of the dental arches for a period of four to eight days, followed by application of elastics; and 3, by means of a wooden block interposed between the right posterior fragment and the median fragment. Daily irrigation of the seat of fractures. Extraction of splinters.

August 11th: All the fragments are in normal occlusion. The rings attached to the teeth of the two posterior fragments were fastened to the anterior gutter-splint, the whole making up a unique fixation gutter-splint. This apparatus was cemented in place until the fracture was completely consolidated. (Author's case.)

Case 20.—A. C., age twenty-two, wounded *September 15, 1915* (rifle bullet). Penetrating wound of the face; comminuted fracture of

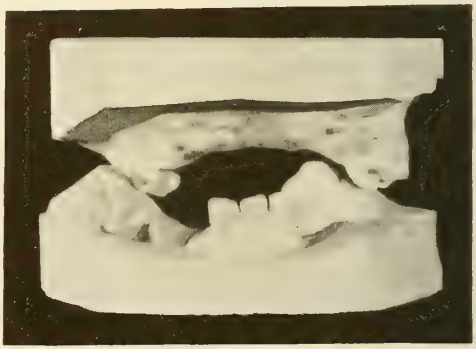

Fig. 279. Fig. 280.

Figs. 279, 280.—Comminuted Fracture of the Horizontal Portion of the Right and Left Inferior Maxilla, Showing the Displacement of the Fragments.
The lips are extremely edematous.

the horizontal portion of the right and left inferior maxilla. Admitted *December 1, 1915.* Condition on admission: The median fragment was displaced downward and forward. The left posterior fragment inclined toward the median line (Fig. 279). Treatment begun *December 10th.* The lips were extremely edematous, lower lip drooped, mouth was agape, and saliva flowed from it continually (Fig. 280). A rubber chin bandage was applied to elevate the lower jaw, and continuous pressure was exerted on the lips by means of a metal band held in place by tapes tied together over the occiput. *December 15th:* Impressions taken and rings applied around the two upper molars, right and left. These rings were connected by a metal rod having on its anterior and median portion a small hook (Fig. 281). In the inferior maxilla the three incisors remaining and the two left molars were provided with two metal gutter-splints with anchoring hooks. One of these was soldered to the an-

terior portion of the lower incisors, the other to the lingual portion of the molars. One elastic band started from the lower gutter-splint and was attached to the metal rod soldered to the anterior portion of the

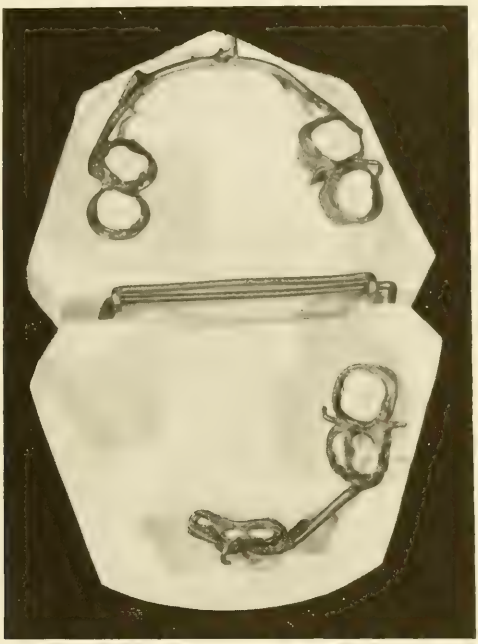

FIG. 281.—METAL APPARATUS IN PLACE FOR THE REDUCTION OF THE FRACTURE IN CASE 20. (After Darcissac.)

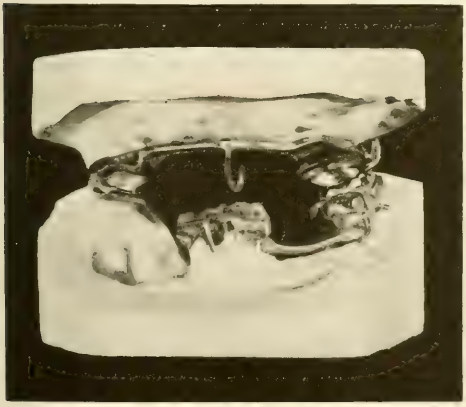

FIG. 282.—METAL APPARATUS IN PLACE FOR THE REDUCTION OF THE FRACTURE IN CASE 20. (After Darcissac.)

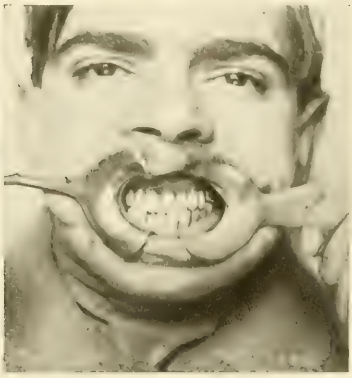

FIG. 283.—TREATMENT TERMINATED. Photo showing the two prosthetic dental appliances and the perfect articulation of the teeth. (After Darcissac.)

upper splint. Another elastic started from the buccal surface of the left upper molars and terminated at the lingual portion of the lower molars of the same side, describing a double curve in the shape of an **S** (Fig. 282).

January 4th: The fragments were reduced to normal occlusion. At this time a plaster model was taken to determine the relation between the gutter-splint attached to the left fragment and the one attached to the median fragment. These two splints were connected by a wire. The next day they were again attached. *February 16th:* Splints removed, slight movement of the fragments was noted. Splints replaced without cement. A large inferior molar, which is very loose, was extracted *April 12th.* By the *end of May* cicatrization was complete. Impressions were taken and two prosthetic dental appliances adjusted. Treatment terminated *June 3, 1919* (Fig. 283). (Author's case.)

PROTECTIVE APPARATUS FOR AUTOPLASTIES

(*a*) **Rhinoplasty.**—1. **Extrabuccal Apparatus** (Fig. 284).—This is used when there are no adequate points of support in the mouth. It

FIG. 284.—EXTRABUCCAL APPARATUS FOR RHINOPLASTY. (After Darcissac.)

consists of a helmet with two lateral extensions directed horizontally forward, with the point of support on the occiput. These two extensions are connected transversely by a flat bar at a distance of about 4 cm. from the lower extremity of the nose. This bar provides the point of attachment for two wires which can be displaced in any given position and immobilized. These wires terminate in vulcanite olives which are inserted into the nares (Valadier's apparatus, Fig. 286).

2. **Intrabuccal Apparatus with the Point of Support on the Cranial Vault.**—Used when the buccal points of support are insufficient (Fig. 285). Only the last molar is left in the superior maxilla on both sides.

3. **Intrabuccal Apparatus with Their Points of Support on the Upper Dental Arch** (Figs. 287, 288).—Definitive protective apparatus. This was used in the case of a man who had a sunken nose and a perforation of the palate (Fig. 288). (Davenport's case.)

(*b*) **Cheiloplasty.—Case 5.**—Figure 289 shows the apparatus before cheiloplasty of the lower lip. The appliance consists of a gutter-

FIG. 285.—INTRABUCCAL APPARATUS WITH THE POINT OF SUPPORT ON THE CAUDAL VAULT FOR RHINOPLASTY. (After Darcissac and Moore.)

FIG. 286.

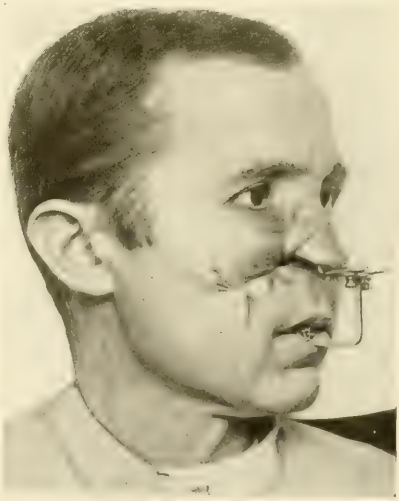

FIG. 287.

FIGS. 286, 287.—INTRABUCCAL APPARATUS WITH THEIR POINTS OF SUPPORT ON THE UPPER DENTAL ARCH FOR RHINOPLASTY. (After Davenport).

splint cemented to the teeth remaining on the right and left fragments of the lower dental arch. The anterior portion of the appliance is removable (Fig. 290).

Figure 290: Reconstructive prosthetic appliance of vulcanite used in the case of a man who had lost the entire horizontal portion of the body

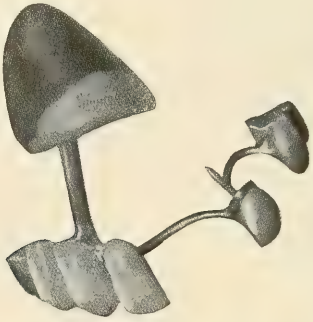

FIG. 288.—SAME CASE AS FIGS. 286, 287. DEFINITIVE PROTECTIVE APPARATUS. (After Davenport.)

FIG. 289.—PHOTO SHOWING THE APPARATUS BEFORE THE CHEILOPLASTY OF THE LOWER LIP. (After Guilford.)

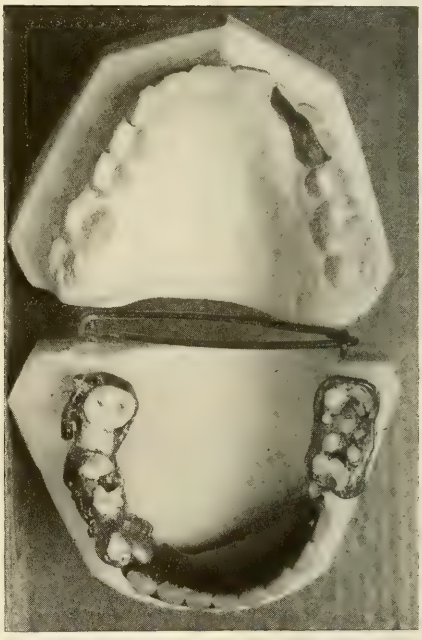

FIG. 290.—SAME CASE AS FIG. 289, GUTTER-SPLINT IN PLACE. (After Guilford.)

of the inferior maxilla. The appliance had its point of support on the superior maxilla. (Duncombe's case.)

BUCCAL ATRESIA

Various appliances have been devised to combat atresia of the mouth following injuries of the lips (Fig. 291). The appliance consists of two vulcanite gutter-splints connected by a spring (Fig. 292). I treated a man in which atresia of the mouth was of such a degree that introduction

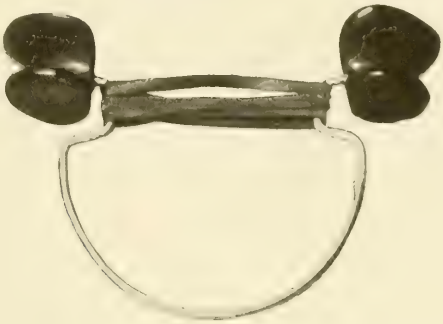

FIG. 291.—APPLIANCE FOR BUCCAL ATRESIA. (After Darcissac.)

of the impression tray was impossible. In addition, the last two molars on both sides were markedly inclined toward the tongue, making it impossible to fit a dental plate around the lingual surface of these teeth.

The apparatus devised in this case was composed of a right and a left portion, connected by a hinge in the middle (Fig. 293), and

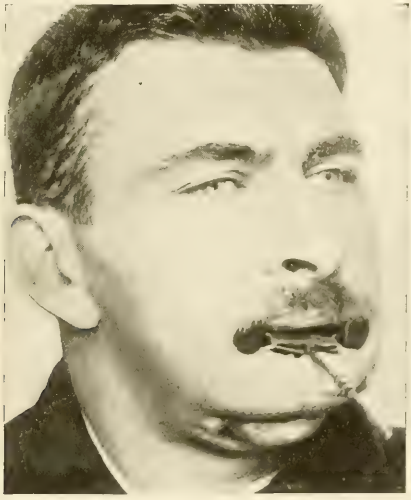

FIG. 292.—APPLIANCE FOR BUCCAL ATRESIA. (After Davenport and Moore.)

provided at its anterior extremity with an elastic band attached to two metal buttons (Fig. 294). The plaster model was taken in two parts. On each model thus obtained two small plaster appliances were prepared with springs adjusted around the teeth. These two

partial appliances were inserted into the patient's mouth and their respective positions obtained by means of a partial impression made with plaster. The appliance was then constructed on the final model.

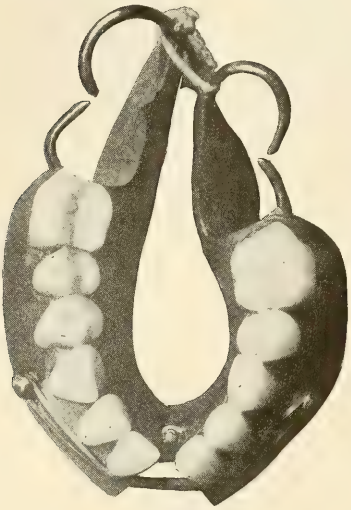

FIG. 293.

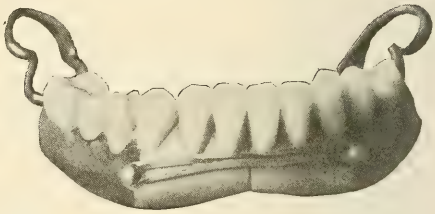

FIG. 294.

FIGS. 293, 294.—APPARATUS APPLIED IN A CASE OF EXTREME ATRESIA OF THE MOUTH. The last two molars on both sides were markedly inclined toward the tongue following multiple fractures of the mandible. (After Darcissac.)

The illustrations have been furnished through the kindness of Dr. Hayes, Chief of the Dental Department of the American Ambulance.

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CHAPTER XXXIX

SURGERY OF THE EYE*

By George E. de Schweinitz, M. D., and B. F. Baer, Jr., M. D.,
Philadelphia, Pa.

Operations for Trachoma.—In addition to the mechanical and operative measures for the relief of trachoma, elsewhere described, the procedure recommended by the United States Public Health Service, and especially by surgeon John McMullen, deserves record. His own description follows:

1. **Modified Brossage.**—"The eyelid is everted by means of a special forceps. Next by the use of two scalpels, one in either hand, the conjunctiva is gradually raised and the full extent of the culdesac is exposed and the granulations are scarified superficially, beginning from the bottom and extending forward toward the ciliary margin. Succeeding this, in some cases, it is well to use a moderately stiff brush with bichlorid solution 1 : 2000. The next step is to use fine mesh gauze sponges, and these are rubbed over the affected conjunctiva until the surface is smooth and the hypertrophy and granulations have been removed. This can be determined by the reappearance of the small blood-vessels to view. The operation is completed by again everting the eyelid and thoroughly washing all blood-clots out of the conjunctiva, etc., with a boric acid solution, followed by the instillation of 2 drops of a 20 per cent. solution of argyrol. The after-treatment consists in cleansing the eyes every three hours with a boric solution and the instillation of a 20 per cent. argyrol solution. This is continued for several days, or until all sloughs have disappeared.

"If a radical operation has been performed the eyes should be examined carefully for the next twenty-four to forty-eight hours for adhesions, and these should be broken up immediately. At the end of about one week following operation, if granulations or rough surfaces are found, these should be lightly touched with a 2 per cent. solution of silver nitrate, repeated two, three, four, or more times a week."

If the trachomatous process is largely confined to the transition fold, and there is no serious lymphoid infiltration of the tarsus itself, excision of the retrotarsal fold or of a strip of the infiltrated fornix may be practised. This operation is also sometimes effective in checking a developing pannus. It is performed as follows:

2. **Simple Excision of the Retrotarsal Fold.**—A subconjunctival injection of cocain (4 per cent.) causes the diseased transition fold of the

* The descriptions in this chapter supplement those on the same subjects in Volumes IV and VI of the System of Surgery, and should be consulted in connection with them.

conjunctiva to bulge forward, and makes plain a line of demarcation between the diseased area and the healthy bulbar conjunctiva. The convex margin of the tarsus is brought within the grasp of two pairs of forceps, and an incision is made in the healthy scleral conjunctiva close to the line of demarcation from the outer to the inner canthus. Müller's muscle, which has a bluish look, is usually recognized when the wound separates and the bulbar conjunctiva retracts. Next, three sutures are introduced through the margin of the bulbar conjunctiva, which is undermined. The next incision is so placed as to separate the transitional fold from the tarsus; the diseased tissue lying between these two incisions, being seized at the inner canthus, is separated from the underlying tissue with blunt scissors and removed. Finally, the needles attached to the sutures already in place are placed through the edge of the tarsus and tied.

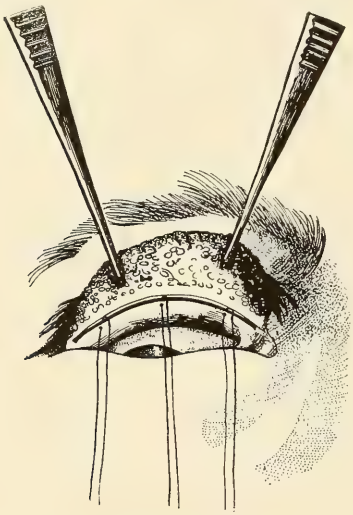

Fig. 295.

Fig. 295.—Combined Excision in Trachoma: First Stage. (Wootton, "Arch. of Ophth.")

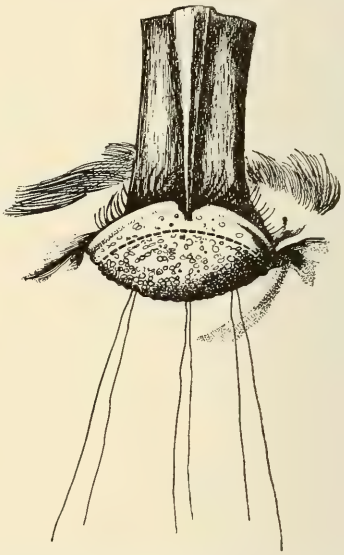

Fig. 296.

Fig. 296.—Combined Excision in Trachoma: Second Stage. (Wootton, "Arch of Ophth.")

Should the lower fornix be selected for this operation, the upper lid is held back and the patient required to look upward. Next, the surgeon everts the lower lid and excises the required strip of conjunctiva. Sutures are rarely necessary. In both instances following the operation the eyes should be freely irrigated with a saturated boric acid solution or one of bichlorid of mercury (1 : 8000), and the operated area dusted with finely powdered iodoform, following which a light compressing bandage should be applied.

For chronic trachoma with tarsal infiltration, chronic trachoma with pannus independently of the tarsal condition, and in gelatinous trachoma of the retrotarsal folds and thickening of the tarsus, the so-called combined excision, which is a mucotarsal excision whereby the affected

transitional folds and the infiltrated part of the tarsus are removed, may be performed as follows:

3. **Combined Excision.**—After free cocainization, the eye being rotated downward, the upper lid is doubly everted and held in position by means of two fixation forceps, in such a manner that the bulbar conjunctiva is drawn upward upon the surface of the tarsus. The first incision, which should penetrate the conjunctiva alone, is made transversely at the juncture of the palpebral and bulbar conjunctiva (Fig. 295), thus separating the diseased and healthy tissue. Injury of Müller's muscle, which lies directly beneath, must be avoided. The retracted bulbar conjunctiva is next separated from the subjacent tissue for a distance of 4 mm. Three sutures armed with a needle at each end are inserted through the lower lip of the wound. Following this dissection the lid is allowed to take the position of single eversion, and a horn or Jaeger plate is placed beneath the cutaneous surface of the eyelid, the margin of which is pressed firmly upon it (Fig. 296). Next an incision is made for the entire length of the lid 2.5 mm. from its inner margin and exactly parallel to it. The lateral horns of the two incisions are joined by a short vertical cut at their external and internal extremities. Thus the boundaries of the diseased conjunctiva and tarsus are fixed. The next step consists in dissecting up this area, care being taken not to injure the orbicularis or Müller's muscle. How much of the diseased tarsus shall be removed depends upon the severity of the condition and the distribution of the lesions; usually the piece removed is about 2 cm. long and 1 cm. broad. Hemorrhage having been checked, the operation is completed by stitching the margin of the bulbar conjunctiva to the rim of tarsus which remains, and it is important that the conjunctiva shall be united exactly to corresponding points of the tarsal cartilage. The eye is closed and the surgeon makes gentle traction on the middle suture in a direction vertical to the lid margin. The point where the suture crosses the upper margin of the tarsal rim is grasped with toothed forceps, one blade being passed beneath the lid, which is then everted. The suture is next passed through the upper margin of the tarsal cartilage at the point designated by the teeth of the forceps. The other sutures are treated in like manner (Fig. 297). In order to avoid pressure on the cornea the sutures may be placed thus, following the method of von Blacowicz. The sutures are armed with two needles, which are passed entirely through the lid,

Fig. 297.—Combined Excision in Trachoma: Placing the Sutures. (Wootton, "Arch. of Ophth.")

the anterior one transfixing the upper margin of the cartilage, the posterior one the aponeurosis, muscle and skin in close proximity. The sutures are tied over a roll of gauze, and may be removed on the fifth day.

Control of Trachoma.—Although not a surgical problem, a few words may be introduced on this subject. In camps, cantonments, and barracks there should be systematic and repeated inspection of the soldiers' eyes after thorough eversion of the lids, and all suspects promptly isolated and kept from mingling with their fellows until the conjunctivæ are entirely restored to a normal condition. It is well known that trachoma is often carried into armies from the outside. It is of paramount importance that the eyes of all recruits shall be inspected before they are assigned to duty in the various camps and cantonments. This is particularly true where, as in our National Army, recruits and drafted men come from those regions in which the prevalence of trachoma among the civil population is conspicuous. The ease with which the infection can spread, especially if in the eyes of the carriers purulent secretion is present, is well known, and the careless use of towels, linen, handkerchiefs, and common utensils cannot be too strongly condemned. Civilian visitors and workmen coming from areas where trachoma is known to exist should not escape inspection, and if any of them have eyes which are not above suspicion they should be forbidden to enter the military zone.

During the past war several epidemics of trachoma occurred among alien laborers at the Western Front, and many of these laborers, especially those from Egypt and China, were affected with this disease. In the B. E. F. trachoma was held in check by an admirable technic which included segregation, disinfection, classification, and treatment.

Among the laborers in our own forces measures similar to those developed by the British were put into operation under the supervision of Dr. George S. Derby (formerly Lieut.-colonel), and a portion of his recommendation is quoted: "Trachoma cases should be isolated in special companies. These companies should be worked in some hospital area where they can be under the supervision and care of the ophthalmic specialist. Until these trachoma cases could be transferred to such a company instructions were given to include them with the Y or conjunctivitis cases.

"Conjunctivitis cases should also be put in special companies and given appropriate treatment. Until this can be carried out, the following course should be adopted: The men should be isolated in a separate barrack or part of a barrack. They should, as far as possible, wash separately, eat separately, and work separately from the clean men. Their towels should be boiled for thirty minutes twice a week, as should handkerchiefs when in use. Local treatment consists in the administration of zinc sulphate drops (0.3 per cent.) twice a day. This treatment may and should be carried out without interfering with labor."

This regulation and those promulgated from the Surgeon-general's

office in the United States were effective, in that trachoma was held in check and no serious epidemic occurred.

Foreign Bodies in the Cornea.—The ordinary *single* foreign body embedded in the cornea or tangled in its epithelial layer must *not* be wiped from its position with a probe or thin stick tightly wound with dry cotton. Such a procedure almost invariably detaches an area of corneal epithelium and offers a port of entrance to microbic infection which only too often results in an extensive corneal ulcer, or at least, a stubborn ulcerative keratitis.

An embedded body—not one which lies upon the surface—should be removed by means of a spud or the point of a Bowman needle, gently worked behind the intruder, which is extracted from its bed by a lever-like motion; the eye, after thorough flushing of the conjunctival sac with a boric acid or saline solution, or 1 : 5000 solution of cyanid of mercury, should be closed, and the lids immobilized with a pad of gauze, or cotton held in place with a strip of plaster or light bandage. In a few hours the corneal epithelium again covers the abraded spot, and the danger of infection from this source has passed.

For an extensive abrasion of the corneal epithelium from whatever cause, in addition to the treatment just described, a few drops of a holocain solution (2 per cent.) afford great relief, and White's ointment (hydrarg. bichlorid, gr. $\frac{1}{8}$; sod. chlor., gr. v; petrolat., ʒv) introduced into the conjunctival sac is of notable effectiveness.

Multiple foreign bodies present a slightly different problem. If the fragments, a dozen or more, are scattered in the cornea, but not too close together, and if they have caused marked ciliary pain and irritation, the natural procedure is to treat each one in the same manner as in the case of a single foreign body.

In the past war there have been observed many cases of multiple foreign bodies due to a peppering of the cornea with fine metallic dust, the particles being so close together that the affected area resembled a cornea which had been tattooed with India-ink. In such circumstances individual removal of the bodies is practically out of the question. Curiously enough, such "tattooed corneas" are often unassociated with much irritation, and the eye may be treated as if it really had been tattooed in the ordinary way. Sometimes the bodies are gradually exfoliated, and those that remain can be later removed in the usual manner. Each such case must be managed according to conditions which exist or subsequently arise, and the eye should be kept under observation.

A deeply placed metallic foreign body, that is, one which has passed through Bowman's membrane and is embedded in the true corneal tissue, is always difficult to remove, and in such instances a stiff, short spud or, better, the point of a cataract knife (not a needle), which is unyielding, used as before described, is the proper instrument.

Should the fragment, if it is a comparatively long one, lie partly within the cornea and partly within the anterior chamber, the difficulty of its removal is increased, especially as there is great danger lest

the efforts to dislodge it should send it into the anterior chamber, where it may readily become entangled in the iris or injure the capsule of the lens. Sometimes it can be removed in the ordinary manner; sometimes after delicately freeing it from the surrounding tissue, should it be magnetic, by means of a hand magnet, and occasionally by inserting a broad, knife-needle, as in the operation for paracentesis of the anterior chamber, in such wise that the surface of the blade is brought beneath the anterior chamber end of the fragment, and it is pushed forward in reach of a small forceps, or the blade acts as an obturator, and prevents the body from slipping into the aqueous chamber, while the point of a stiff cataract knife deftly pries it from its lodgment.

Fragments of unburnt cordite striking the eye and becoming embedded in the cornea or entangled in the meshes of the conjunctiva have proved in the past war to be very troublesome and dangerous bodies. They should be as speedily as possible picked out of the cornea with a sharp needle or point of a knife; from the conjunctiva it may be necessary to dissect out the particles. Should the fragment enter the anterior chamber, iridectomy (that is, removing the piece of iris in which the body is entangled), with irrigation of the anterior chamber, may be required, or, failing in this, an attempt may be made to pick off the pieces lying on the iris through an incision at the corneoscleral border —a difficult procedure and one requiring skilled hands.

Intra-ocular Foreign Bodies.*—The lodgment of foreign bodies within the eyeball may be in the anterior chamber, the posterior chamber, the crystalline lens, the vitreous chamber, the ciliary body, choroid or retina, and has occurred with great frequency in the past war. During the war about two-fifths of these bodies were magnetic; their removal, therefore, by means of a magnet was the operative procedure of choice, and generally foreign bodies of this class were best secured, save those in the anterior chamber, by a giant magnet, for example, the Haab instrument, or by "sling magnets," of which those designed by Sweet, Lancaster, or Lister are types.

There are three routes along which the foreign body may be attracted by the magnet: (*a*) Through the wound of entrance, advisable if the body is of large size; (*b*) from the regions posterior to the plane of the iris, *i. e.*, the ciliary body, lens, vitreous chamber (the usual situation), choroid or retina, into the anterior chamber, the so-called anterior route; (*c*) through a small opening made in the sclera, its position being determined as the one nearest to the situation of the foreign body by means of *x*-ray localization, the so-called scleral or posterior route.

If the wound is of considerable size in the cornea or sclera, it is indicative of a large intra-ocular body, one that it would be dangerous to attempt to remove by any other path. The magnet must be approached slowly, the current being turned on from a distance, otherwise the foreign body may make a sudden jump forward and drag the surrounding tissues with it, or cause a large intra-ocular hemorrhage.

* This paragraph supplements the one on this subject in Volume IV, and should be read in connection with it.

If the anterior route is chosen, and this was the operation of choice among British surgeons during the war, and is of many of our own surgeons in army and civilian practice, the magnet's extension point is brought in contact with the pole of the cornea, the current alternately turned on and off, in order to draw the body through the suspensory ligament of the lens into the posterior aqueous chamber. When the iris is seen to bulge, indicating the presence of the body behind it, the current is turned off and the direction of the eye so changed that the full force of the magnet when the current is again turned on shall be parallel to the surface of the lens. The body having been drawn gradually into the anterior chamber, a small opening is made with a narrow keratome about 3 mm. below the limbus, and no aqueous spilled if possible. The extension point of the magnet is directed next outside of the cornea over the foreign body, which is coaxed along the posterior surface of the cornea into the corneal incision, through which it is drawn with the aid of a small hand magnet.

If the scleral route is chosen, at the point of election, as determined by *x*-ray localization, after raising a suitable conjunctival flap, a small meridionally placed incision is made through the sclera, to which the magnet is applied, and through which, while it is retracted with small, non-magnetic retractors, the body is withdrawn. The conjunctival flap is next replaced and sutured into position.

In the hurry and stress of war surgery *x*-ray localization was not often possible. The British rule was that if localization was likely to cause some hours of delay, as its assistance was not essential, it should be omitted; naturally in the zone of the advance it practically always had to be omitted. Hence the scleral route, depending as it does on *x*-ray localization, could not be employed except in surroundings where time and special apparatus were available.

Magnetic foreign bodies in the anterior chamber can almost always be removed by means of a small magnet through a corneal incision; occasionally such bodies are so entangled in the iris that an iridectomy is required to extract the intruder from the piece of iris in which it is fastened.

Whether intra-ocular metallic foreign bodies shall be removed along the anterior or posterior route must be settled by the surgeon in charge of the case. Personally, our experience is in favor of the posterior route after *x*-ray localization of the fragment, save only when there is a large, fresh wound of entrance and a body of considerable size, as already explained, and in the case of very small bodies. Points of importance are that the operation shall be done as soon as possible after the accident, that not infrequently small foreign bodies penetrate and leave no external evidence of the point of entrance—hence the importance of *x*-ray examination of any eye which has been exposed to the possibility of such an accident. The wound of entrance, or one made during the operation of extraction of the foreign body, must be carefully covered with a conjunctival flap (see Conjunctivoplasty).

Non-magnetic Foreign Bodies.—If in the anterior chamber, these

can usually be extracted through a suitable incision with forceps; if within the vitreous chamber, in a few instances they have been removed through a scleral incision, the extracting forceps being guided by simultaneous opththalmoscopic examination. Often the haziness of the media prevents such a procedure. They have also been extracted in like manner after a careful localization by means of *x*-rays. Small fragments of glass, the eye being uninflamed and not infected, usually cannot be safely extracted, and generally may remain, as usually they do not produce irritation. Particles of copper, on the other hand, according to Leber are apt to evoke a purulent inflammation merely by the chemical action of the metal. During the past war a few non-metallic bodies have been located by a specially devised fluoroscope, and extracted through an incision, but such fortunate operative results are rare.

Wounds of the Eyeball.—The treatment of corneal, conjunctival, and corneoscleral wounds, and of wounds of the sclera has been discussed elsewhere (Vol. IV, p. 885), but the experience of the late war has emphasized the value of certain procedures, which should, therefore, be elaborated.

(1) Frequently in warfare, and not infrequently in civilian practice, a considerable period of time may elapse before a patient who has received a penetrating wound of the eye can be transported to a hospital or other surroundings where the treatment, operative or otherwise, shall take place. In these circumstances "first aid" is of importance to prevent infection which comes readily from the conjunctival sac, the ciliary margins and the lacrimal passages through the puncta, where pneumococci, streptococci, and pathogenic staphylococci have their habitat. If possible the surface of the lids and surrounding facial area and the palpebral margins should be scrubbed with soap and water, followed with bichlorid, 1 : 2000; neither of these applications should enter the conjunctival sac. The conjunctival sac should be flushed with saturated boric lotion or saline solution (this area should not be sterilized with strong germicides); and if the puncta are tumid the angles of the inner canthus should be dusted with finely powdered iodoform, which temporarily seals these points and prevents septic fluid coming from the conjunctival sac from gaining entrance into the conjunctival sac. The nasal passages should be irrigated with permanganate of potassium, 1 : 5000, and the eye covered with a sterile pad and a light bandage.

(2) A penetrating wound of the eye, with prolapse of the uveal tissue or of the lens capsule, that is, a wound through the cornea, or at the corneoscleral margin, or one through the sclera, with prolapse of the choroid and vitreous, should be treated as follows: Having carefully ascertained that no foreign body is within the globe, after disinfection of the conjunctival sac, the prolapsed tissue should be cleanly removed. If there is a hernia of the iris it is important that the prolapsed tissue should be seized in such wise that it can be freed from the grip of the surrounding tissue and drawn forward, so that when the

prolapsed portion is cut away the elasticity of the iris fibers can snap back the iris, and there shall be no entanglement of the cut edges in the cornea or corneoscleral wound.

If the choroid or vitreous present through a scleral wound, the foreign material having been carefully removed, the edges of the cut should be pencilled with a 5 per cent. solution of iodin, and it should be covered with conjunctiva in such a manner that the sutures, preferably of fine silk, should not overlie the wound in the sclera. The subconjunctival tissue, with its rich blood-supply and abundant adhesive exudation, quickly seals the wound. In large wounds of the sclera prior to placing the conjunctival covering some surgeons coapt the cut scleral edges with sutures; usually, however, these scleral sutures are unnecessary.

After any of these operative procedures the eye should be closed with a light dressing of cotton and gauze, and iced compresses applied for twelve to twenty-four hours, the chilled pads, frequently changed, being placed directly on the dressing, which hence should be sufficiently thin to admit the influence of the cold. The sutures may be removed at the end of a week, or even sooner. Occasionally an incised wound through the cornea or corneoscleral junction, after the prolapsed iris is abscised, coapts itself perfectly and healing takes place promptly without other operative procedure. As tetanus occasionally follows eye injuries, especially if there has been earth contamination, an injection of antitetanic serum is indicated.

In many instances the wound is large, gaping, irregular; it may extend from the cornea into the sclera, or divide the cornea from one margin to the other. Such wounds should be protected by a conjunctival covering, as already noted (Vol. IV, p. 885), a practice long in vogue and highly recommended. But the experiences of the past war have afforded large opportunities for such operative procedures, and have so well established their value that additional description of the technic is advisable.

Conjunctival Conjunctivoplasty.—If the wound is situated peripherally, for example, at the corneoscleral border, the conjunctiva is incised along one-half of the corresponding circumference of the cornea, undermined sufficiently, and drawn across the cut and fastened by means of two sutures placed at each end of the incision; at least one-half of the cornea can be covered in this manner (Fig. 298). For a wound crossing the cornea almost entirely, or for one situated quite centrally, it is more expedient to cover the defect by means of a bridge of conjunctiva. To form it one cut is directly circumcorneal and a second one placed about 8 mm. from it. The piece of conjunctiva between these two incisions is drawn over the injured area and fastened by means of a suture above and below (Fig. 299).

In gaping wounds across the cornea it may be necessary to cover the entire corneal area with conjunctiva. For this purpose the conjunctiva is incised around the entire circumference of the cornea, undermined for approximately 6 mm., and then drawn over the cornea by

means of a purse-string suture (de Wecker), or fastened after the manner of Kuhnt (Figs. 300, 301). After the corneal wound has healed the conjunctival covering is removed and restored to its original position. Even if a wounded eye with prolapse of the iris is not seen until there is incarceration of the iris in the wound, the prolapse, if no infec-

FIG. 298.—BY PASSING THE SUTURE THROUGH A FOLD IN FLAP AND THEN THROUGH A FOLD ABOVE A FIRMER HOLD CAN BE OBTAINED, AND THE ANCHORING HOLD SHOULD INCLUDE EPISCLERAL TISSUE. (After Kuhnt, "War Manual," No. 3.)

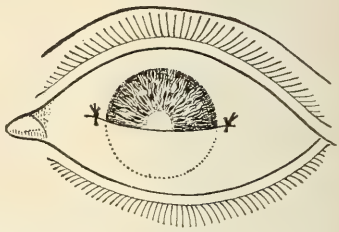

FIG. 299.—FLAP IN PLACE. (After Kuhnt, "War Manual," No. 3.)

tion exists, may be amputated in the usual manner and the opening covered with a conjunctival flap.

In any of these instances should no inflammatory reaction appear (iritis, iridocyclitis) within a few days, the likelihood of its manifestation and the danger of sympathetic ophthalmia are greatly diminished.

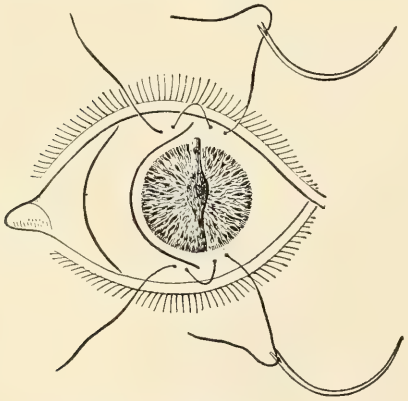

FIG. 300.—BRIDGE. (After Kuhnt, "War Manual," No. 3.)

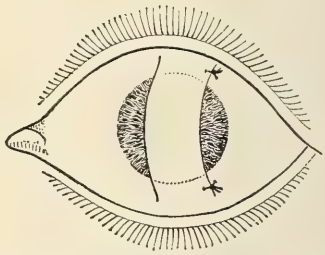

FIG. 301.—BRIDGE IN PLACE. (After Kuhnt, "War Manual," No. 3.)

If such complications arise in spite of conservative surgery, and the danger of sympathetic ophthalmia arises, radical interference is promptly indicated. There is no question that careful treatment along the lines suggested is a means of saving many eyes which in earlier days were needlessly sacrificed.

Sympathetic Ophthalmia.—Without entering into a discussion of the pathogenesis of sympathetic ophthalmia, as yet undecided, although the metastatic theory, that is, the transmission of a specific unidentified organism by the blood-stream, at present, at least, appears to be the most satisfactory (see also page 887, Vol. IV), the question In what circumstances does an injured eye constitute a menace to the fellow eye through the development of this disease? requires additional answer.

Based on the experience of this war, the following reply may be made, and it applies also in largest measure to the accidents of civilian life: This complication need not be seriously considered in case the eye is hopelessly shattered, is blind from a contusion without perforation, or is suppurating (there are a few exceptions to this statement). If sympathetic ophthalmia ever occurs after disorganization of an eye unassociated with prolapse of the uvea or lens capsule, it must be exceedingly rare. A retained, sterile, chemically inert foreign body of itself does not cause sympathetic ophthalmia; but secondary infection or infection at the wound of entrance may create this complication. In general terms, sympathetic ophthalmia is most likely to occur if a plastic uveitis (iridocyclitis) arises as a result of a penetrating wound of the cornea or anterior portion of the sclera, especially in the "danger zone," associated with prolapse of uveal tissue (iris, ciliary body, and choroid) or lens capsule. Persistent cyclitis or uveitis, gradual and increasing lowering of the intra-ocular tension, with progressive failure of vision and continual photophobia, are signals of grave danger, indicating immediate enucleation of the injured eye.

The minimum time which elapses between the incidence of the injury and the development of sympathetic ophthalmia, save only in rare instances, is fourteen days; it must be feared during the first twelve weeks after the injury, especially between the sixth and the twelfth weeks; it is exceptional after this period, that is, after the third month.

This much-dreaded ocular disease, in spite of the numerous penetrating injuries of eyes which the past war has unhappily furnished, has been uncommon as compared with its reported frequency during our own Civil War and during the Franco-Prussian War of 1870. Thus, in a series of wounded eyes recorded in enemy and allies statistics, totalling 1459, not a single case is reported, and only one case among 6200 wounded soldiers was noted by Morax. In contrast, it was stated by the late Mr. Jessop that in the War of 1870 about 50 per cent. of eye injuries resulted in sympathetic ophthalmia, figures, as has been pointed out, which indicate that almost certainly many of these cases were not really sympathetic ophthalmia, but that sympathetic irritation, a totally different condition, was included.

Four factors have been potent in reducing to a gratifying minimum the incidence of sympathetic ophthalmia in the past war: (1) Accurate recognition of eyes so injured and inflamed that they should be sentenced to prompt excision; (2) proper early treatment of injured eyes; (3) the healthy general condition of most of the soldiers; (4) abstinence from unnecessary minor operative procedures.

The foregoing statements and statistics are recorded because they demonstrate that a careful study of each injured eye should be made before excision is decided upon and that conservative treatment should be instituted, with all due procedures to prevent infection. Unfortunately, many eyes were sacrificed in the earlier years of the war which might have been spared, and a good rule is that conservative treatment is indicated where the ocular injury is such that it still permits conservation of the globe; should pain or irritation be present, the eye being blind or practically blind, and continue at the end of a month, excision or one of its substitutes is imperative. The indications for earlier interference have been given. All injured eyes must be watched carefully and intelligently; frequent blood examinations should be made; mononucleosis is considered by Gradle, Browning, and Lawson as indicative of the imminence of sympathetic ophthalmia.

Naturally, eyes which are hopelessly and extensively injured, especially the "shattered eyes" so common in the war, require immediate enucleation; conservative surgery is out of the question.

Enucleation of the Eye; Its Modifications and Substitutes.— Although enucleation and its substitutes and modifications have been dealt with in a previous chapter (Vol. IV, p. 901), certain directions, considering the experiences of the past war, during which many eyes were removed by those who were not specially trained in ophthalmic procedures, should be emphasized. An enucleation of an eyeball in which no attention is paid to the preservation of the relationship between the conjunctiva, tendons of the ocular muscles, and the capsule of Tenon is a brutal operation which should not be performed. The old-fashioned enucleation by the Bonnet or Vienna method (*loc. cit.*, p. 901) can be greatly improved, even in the absence of an implantation into the capsule of Tenon, by securing the tendons of the exterior ocular muscles.

Suker sutures the severed ends of the recti muscles one to the other, after which the conjunctiva from above and below is brought over the muscle stump with a continuous suture, which also attaches the conjunctival covering to the muscle stump. Priestley Smith pinches up a narrow horizontal fold of the conjunctiva over the internal rectus, so as to include the subjacent connective tissue and muscle, and carries a black silk suture through these structures with a curved needle, the suture being tied firmly but not too tightly. In a similar manner the other straight muscles are attached, after which the enucleation is carried out in the usual manner and the conjunctival aperture closed with one or more vertical sutures.

Freeland Fergus' method of enucleation is as follows: The conjunctiva is divided freely over the external rectus so as to expose thoroughly that muscle. As soon as this is done, one blade of the scissors is passed beneath the muscle and it is divided, a small portion of its tendon being left still attached to the sclerotic. This portion is taken hold of with the forceps, and the eye is gently rotated toward the inner canthus. When in this position the optic nerve is severed. After the

division of the nerve the movement of rotation is continued, and all the other tissues, as they come in view, are resected as closely as possible to the sclerotic. A few snips of the scissors suffice. The wound, which is always neat, may be closed with or without the insertion of a gold ball, or with suturing together of the muscles, as recommended in the following paragraph.

The following technic yields satisfactory results: The conjunctiva is divided as close as possible to the corneal margin; each rectus tendon is next seized with forceps, separated from the sclera, and drawn forward to the edge of the cut conjunctiva, where it is fastened with a black silk suture. The eyeball is next enucleated in the ordinary manner, hemorrhage being checked by packing the cavity with a small wad of sterilized gauze. Finally, after removal of the packing, the edges of the conjunctiva are united with interrupted sutures, which are generally placed in a horizontal direction, and which also include the capsule of Tenon. The usual dressing is applied, both eyes being bandaged for twenty-four hours.

The effect of this operation, whereby each rectus tendon is "advanced" to the margin of the conjunctiva and prevented from retracting, is to give a movement to the conjunctival bed very much greater than that which is secured after the ordinary enucleation.

A number of modifications of securing the ocular tendons have quite recently been described. One designed by Frederick Krauss, of Philadelphia, whereby the relations of the recti tendons with Tenon's capsule are preserved, deserves especial attention. (See Bibliography.)

Evisceration of the Eyeball.—The indications for evisceration of the globe and the technic of the operation are recorded elsewhere (Vol. IV, p. 903), but in view of the fact that the question of evisceration, in place of enucleation, has again attracted attention during the past war, a further mention of this procedure is made. In place of the ordinary evisceration (*loc. cit.*, p. 903) the method of Gifford may be utilized, which he describes as:

(1) **Simple Evisceration of the Eyeball.**—A conjunctival flap is laid back by two incisions, one along the corneal margin from near the insertion of the external rectus to that of the superior rectus, the other extending from the lower extremity of the incision obliquely upward back to the retrotarsal fold. A meridional incision $\frac{3}{4}$ inch long is next made through the sclera midway between the external and superior recti, extending from within 3 mm. of the corneal margin toward the posterior pole of the eye; the eye then being turned down, the contents of the globe are scraped out through this incision, which is held apart with hooks or forceps. The conjunctival flap is next replaced by two or three sutures, no scleral sutures being employed. The advantages of this operation are that, although the stump gradually diminishes in size until the cornea is reduced to a mere facet, on the average a much larger stump is finally obtained than where an evisceration plus a keratotomy without the introduction of any foreign body is done.

We are satisfied that the indications for evisceration, be it according

to the ordinary method, or according to Gifford's plans, have a comparatively limited range, as is elsewhere recorded (*loc. cit.*, p. 903).

As a substitute for evisceration Sir William Lister has advocated and practised enucleation of a septic eye with this modification, namely, that a fringe of sclera about 10 mm. in width is allowed to remain and surround the optic nerve entrance, avoiding, therefore, opening the optic nerve sheath and the danger of conveying infection through this route. With this procedure we have had no experience, but any recommendation from Colonel Lister must command attention.

Enucleation Followed by Implantation of an Artificial Globe in Tenon's Capsule.—Implantation of a sphere of gold or glass in Tenon's capsule following an enucleation, and associated with proper securing of the tendons, is an operation which yields such excellent cosmetic results that it should be an operation of choice in the absence of contraindications, for example, malignant growths of the eyes, sympathetic ophthalmitis, and septic eyeballs or sockets. The operation has been briefly described (Vol. IV, p. 904). The size of the ball should not be less than 14 mm. in diameter, and some surgeons, notably Dr. Allen Greenwood, insist that the cosmetic results are better and more lasting if an even larger ball is utilized—18 to 20 mm. in diameter. Glass balls are most frequently used, but we are convinced that gold spheres are preferable.

In performing this operation, after the enucleation the capsule of Tenon should be carefully sutured over the ball with fine silk, and the conjunctiva sutured vertically over this. The muscles may be secured, as has already been described. If this technic is conscientiously followed later extrusion of the ball is most uncommon. A freely moving stump is secured, which transmits its motion to the artificial eye, which usually may be adjusted at the end of ten days or two weeks. The buried silk sutures in the capsule of Tenon cause no trouble; those in the conjunctiva should be removed at the end of a week. The line of conjunctival suture should be painted with a 5 per cent. solution of iodin.

Implantation of Cartilage.—The implantation of glass or gold balls in the manner described in the previous paragraph does not meet the favor it has received from American surgeons among English and French ophthalmic surgeons. Aymard, for example, places himself on record that plastic surgeons are a unit as to the superiority of natural tissues in contrast to metallic or glass prosthesis. He is satisfied that transferred cartilage establishes fresh communications with the blood-vessels in its vicinity, and becomes fixed to the capsule in recent enucleations. Even if the cartilage after implantation is transformed into a species of fibrous tissue, it is believed by many surgeons that the cosmetic result is not disturbed. For the purpose of making cartilage implantation generally the seventh or eighth rib is selected and the globe of cartilage removed with a trephine of such size as is suited to the conditions. The cartilage having been introduced within Tenon's capsule, it is sutured to the inside or, if possible, the four straight muscles

are attached by means of sutures to this cartilage sphere; the rest of the operation proceeds as has already been described. It has been stated that such grafts may be used even in the presence of septic eyes or septic sockets. We have no experience in this regard, but doubt the propriety of an implantation in a septic socket. Gillies uses cartilage graft prosthesis in shrunken sockets (late implantations), the graft being formed in the shape of a cup and ball.

In place of human cartilage it is the practice of some surgeons, notably Magitot, to use formalized cartilage taken from a calf or lamb rib. This is placed in formol, 10 per cent., for three days, and afterward freed from the formol by successive washings in sterile water. It is most important that there shall be a thorough removal of all traces of the formol before the cartilage is implanted, which can be shaped to any size that is required for the purpose of the implantation.

Terrien recommends a graft of cartilage, generally rib cartilage, 1.5 cm. in length, to which the tendons of the rectus muscles are sutured. In default of the graft prosthesis he generally improved the appearances by using artificial stumps of hard ebonite shell in an envelope of soft India-rubber, which was molded to the bottom of the conjunctival sac, or molds of wax were placed behind the artificial eye.

Fat Implantation Into Tenon's Capsule.—After enucleation of the eyeball this procedure, originally proposed and practised by Barriquez, came into prominent notice after Bartels called attention to the operation in 1908. The eyeball is enucleated, the recti muscles being secured in the manner already described. A mass of fat taken from the abdominal wall is inserted into Tenon's capsule so as to fill, but not to overstretch it. The muscles are sutured crosswise or by means of a purse-string suture, and next the cut conjunctiva is united with stitches. Either catgut or silk may be employed.

A modification of this operation has been performed in that the sphere of fat is covered with fascia lata, over which the muscles are secured in the usual manner.

Evisceration of the Eyeball with the Insertion of an Artificial Vitreous (Mules' Operation).—This operation, fully described in Volume IV, page 903, at one time extensively practised, but in recent years less frequently utilized, yields most satisfactory cosmetic results. Doubtless owing to a not infrequent escape of the "artificial vitreous," and the occasional severe reactions which followed its performance, the various types of implantation which have been recorded have largely taken its place.

Recently T. J. Dimitry has designed an operation which is analogous to Mules' procedure, but which includes certain modifications. It consists in an evisceration of the sclera, with the removal of a section posteriorly, including a severance of the optic nerve. A gold ball is inserted within the sclera, and the anterior opening is closed. This posterior window in the sclera and a special method of attaching the conjuctiva are the original features of this operation.

Some years ago Victor Ray devised and practised an operation that

is almost identical with the above procedure except that he used fat to fill the scleral cup instead of a gold ball.

Implantation Into the Orbit After Remote Enucleation of the Eyeball.—To improve the appearance of artificial eyes where the socket is too deep and there is sinking in of the upper lid as the result of a complete enucleation performed at some remote period, a sphere of gold or glass may be implanted into the orbit. Dr. L. Webster Fox operates as follows: If the operation is to be performed on the right orbit, the eyelids are separated by a speculum, the conjunctiva is grasped up and in above the inner canthus, and the tissues are well pulled out. Next, a Beer's knife or curved keratome is passed through the tissues somewhat obliquely and well down into the orbit, and an opening made large enough for the insertion of the globe behind the tissues. This opening may be enlarged with curved scissors to the desired size. When ready, a gold ball is inserted through the opening, which is closed with two stitches, and over which a shell is placed, modeled after an artificial eye. The eyelids are then closed over this shell, which is left in place for twenty-four hours. The stitches are taken out on the third day. If the operation is to be performed on the left orbit, the incision is made up and out above the external rectus muscle and the dissection carried out as above described.

After healing, the artificial eye is inserted in the usual manner, and, naturally, the support of the implanted globe improves the cosmetic result. It is a fact, however, that a comparatively large percentage of these balls escape, or are extruded; moreover, the sphere may leave its central position, causing the overlying glass eye to be turned in some eccentric direction. To obviate this a method may be practised as follows: The conjunctiva is incised in a horizontal direction and dissected from the underlying tissue. Tenon's capsule is identified and freed, and within its space the ball is placed. If possible the ocular muscles are found and secured in the manner already described, the whole procedure being a replica of a primary implantation. In place of a gold or glass sphere cartilage may be used, or fat wrapped in fascia lata.

These late implantations are difficult, and should be undertaken only after careful consideration, and should be performed by those who are well trained.

The insertion of sponge-grafts, glass balls wrapped in a sponge-layer, or paraffin sphere have been recommended, in primary and late implantations, but possess no advantage over those which have been described; silver balls are not advisable, as they undergo oxidization within the tissues.

Operations for Prosthesis in Cases of Cicatricial Orbit.—Contraction of the conjunctival sac and the formation of cicatricial bands, especially after lime and acid burns, trachoma and scar formation from wounds, or following badly performed enucleations, may render the introduction of an artificial eye impossible. The same state of affairs may be brought about by the neglect to wear a suitable eye. Numerous

operations have been devised to enlarge the socket in these circumstances, mere incisions of the contracting bands being entirely insufficient.

If the cavity of the orbit is slightly or only partly obliterated, it is sometimes possible, after dividing the cicatricial bands, to form a socket, in which later an artificial eye may be placed, by introducing lead plates, which are bent to conform to the size of the cavity, and from time to time increased in size. The plate gradually creates a groove in the dense tissue, into which afterward the margin of the artificial eye is fitted.

During the recent World War, in which the percentage of wounds of the orbit was very high, as high as 11 per cent. in some statistics of injuries of the eye and orbit, partially or entirely cicatrized sockets were only too common. It would not be possible in a chapter of such limited scope as the present one to describe the many ingenious and effective procedures which have been elaborated, and therefore only a few general principles and one or two methods can be recorded.

In general terms, the new culdesac may be formed by pedunculated flaps from skin adjacent to the orbit, or it may be lined by transferred integument (Wolff or dermic grafts), or by Thiersch grafts (epidermic), in each instance molded in place, after suitable dissection, by means of various conformers.

To prevent subsequent contraction of the newly formed socket the dissection must be sufficiently deep, extending, as Wilder well maintains, to the margin of the orbit, exposing the periosteum. All scar tissue must be dissected away; to allow sufficient room for the conforming plates or molds it is often necessary freely to divide the outer canthus.

In not a few instances of contracted socket, especially where obliteration is not complete, or where it is not too dense, after the new culdesac is formed by suitable dissection and freed from scar tissue, they may be lined with a Thiersch graft, preferably taken from the inner aspect of the arm, wrapped around (the raw surface outward) a mold of dental modeling composition, or "stent," as it is usually called. This substance, after immersion in hot water, can be molded into any shape required. The graft must be somewhat larger than the area to be covered, and the mold of stent so formed that it neatly presses the graft over the entire surface of the new socket. After it is in place the lids may be stitched together, and should not be disturbed for at least ten days. If successful, after removal of the "stent" it will be found that the graft "has taken," and covers the desired surface. Even if a part of the graft is lost, a second grafting over the exposed area is perfectly feasible. In some cases it is possible, before the graft is put in place, to introduce a piece of cartilage, as before described (page 290), which forms a base on which the artificial eye rests.

Weeks restores the culdesac with Wolff grafts, which are secured by sutures which anchor them to the periosteum and emerge on the cheek. He insists that success depends on attaching the implanted

flaps, whatever their nature may be, to periosteal or epiperiosteal tissue at the margins of the orbit.

Restoration of the lower culdesac may be secured with Maxwell's method, who operates as follows: "An incision is made in the floor of the socket and carried downward behind the lower lid. A semilunar flap about 8 mm. in width at its widest part is marked out on the skin, its upper concave border being about 5 mm. below the edge of the lower lid. The incision along the upper border of the flap is made to communicate with the bottom of the wound in the socket. The flap is now dissected up from the subcutaneous tissue, except an area represented by the dotted line in the figure. The two ends of the flap (*a* and *b*) are passed through the opening into the socket and sutured to each end of the socket incision (*a* and *b*), and the borders *A'* and *B'* being also passed through, are sutured to *A* and *B* respectively. The space on the cheek is closed and the operation completed by putting in a temporary glass eye or shell. This should be as nearly as possible

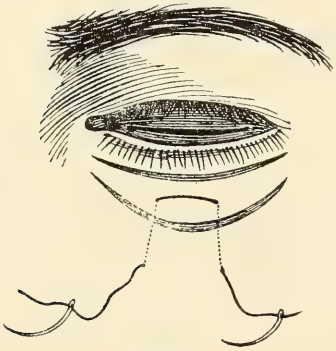

Fig. 302.

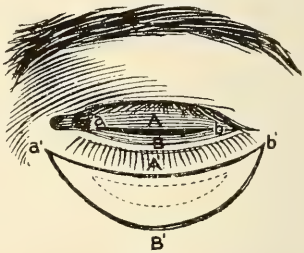

Fig. 303.

Figs. 302, 303.—Maxwell's Operation to Enlarge a Contracted Socket. ("Ophthalmic Review," vol. xxii.)

of the size and shape as that which is to be ultimately worn. This glass eye prevents the new sulcus from being obliterated by contraction and gives it a suitable shape. It cannot safely be taken out for at least a week, as the skin incision might be opened in so doing. If there be secretion, the space behind can be flushed out by a lacrimal syringe armed with a fine curved nozzle, which can be introduced under the eye at the inner or outer canthus. A glass shell with a hole in front is preferable to a glass eye, because it allows a syringe to be more easily used, and, being transparent, a view of the parts behind can be obtained" (Figs. 302, 303).

To get a good result the following points should be attended to:

(1) Make the incision in the socket as long as the space will permit, and see that this length is maintained throughout its entire depth.

(2) Make the flap of skin considerably longer than the incision in the socket.

(3) When dissecting up the flap of skin, leave undisturbed a portion (dotted line in figure) equal in length to the socket incision. This

ultimately forms the fornix or sulcus. If a shorter portion is left the sulcus is apt to become **V** shaped, which would require a specially made glass eye.

(4) When closing the space on the cheek, as the lower border is longer than the upper, great care should be taken to equably distribute the excess, so as to avoid puckering. When this has been neatly done the line upon the face becomes quite invisible after a few months.

Should the operation have to be performed on a deeply sunk orbit, the procedure might be facilitated by a preliminary division of the external canthus.

For those cases where the socket, although shrunken, still retains a certain amount of conjunctiva, an operation designed by Meyer Wiener may serve a useful purpose:

"An incision (Fig. 304, *A*, *B*, *C*) is made through the conjunctiva, and a flap, including only the conjunctiva, is carefully dissected down to the lid margin (Fig. 304, *A*, *C*). This dissection, after being started with a knife, can easily and quickly be finished with a small curved

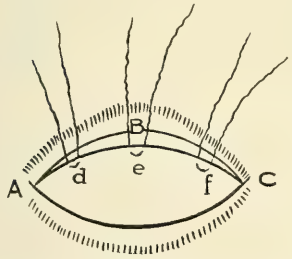

Fig. 304.

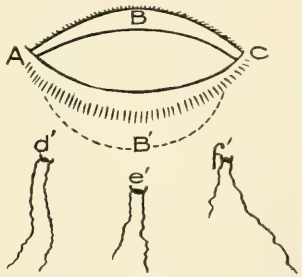

Fig. 305.

Figs. 304, 305.—Wiener's Operation for Restoration of Incompletely Occluded Socket. ("Trans. Amer. Oph. Society," vol. xvi, p. 186, 1918.)

blunt scissors. The dissection is then continued with the scissors so as to loosen the skin below the lid margin (Fig. 305, *A*, *C* to *B*), leaving a raw surface toward the bulbar side extended from *B* to *B′* and *A* to *C* (Fig. 305), and on the palpebral side *A*, *B*, *C* (Fig. 305). Then sutures with a needle on either end are introduced at the points *d*, *e*, *f* (Fig. 304), and passing them through the bottom of the newly made sulcus are brought through the skin at *d′*, *e′*, *f′* (Fig. 305) and tied over a button. This gives a conjunctival covering for the lower lid and leaves the bulbar surface *A*, *B*, *C*, *B′* (Fig. 305) to be covered. This is done by covering a lead plate, previously shaped, with grafts from the thigh, placing them carefully in position. A dressing is then applied and both eyes bandaged, the patient remaining undisturbed in bed for four days, when the outside dressings are replaced by clean ones without disturbing the plate. On about the eighth day the plate may be removed, cleaned, and replaced. The glass eye can usually be worn by the tenth or fourteenth day. The stitches at *d′*, *e′*, *f′* (Fig. 305) are not removed, but are tightened each day after the fourth day until they pull through."

Schwenk and Posey resort to a combination of the Maxwell operation (*q. v.*) and a technic of their own in restoration of the entire orbital sac, as follows:

A careful separation of the margins of the two lids from one another and a free dissection of the underlying tissues is secured. Next follows a division of the external canthus. The lower culdesac is now restored by Maxwell's method and the upper by transposing a long flap taken from the skin of the forehead above the brow, care being taken, however, that no hairs of the brow are included in the margin of the flap.

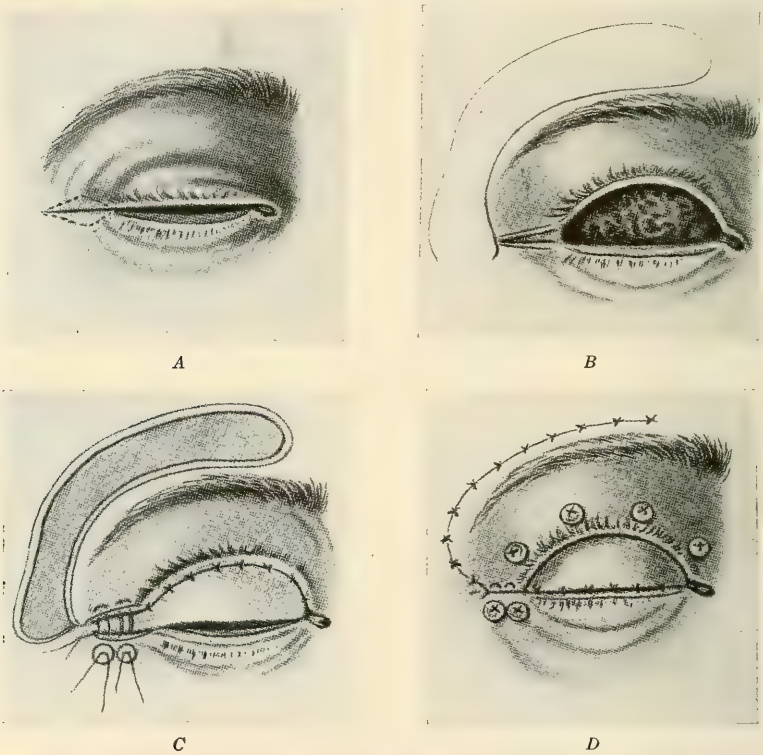

Fig. 306.—Schwenk and Posey's Operation for Restoration of Contracted Socket.

A, Division of external canthus and separation of the lid margins; *B*, outline of pedicled flap; *C*, transposition of flap from forehead into upper portion of culdesac, and restoration of external canthus; *D*, coaptation of flap margins to parts adjoining. ("Trans. Amer. Oph. Society," 1918.)

The edges of the flap must be nicely coapted to the margin of the upper lid, and the upper border of the skin secured by the Maxwell procedure. The next step is of great importance, namely, the restoration of the external canthus, for unless this be accomplished at this time the conformer which is introduced between the lids at the completion of the operation will not be retained in the culdesac, and a subsequent operation for the restoration of the canthus will be necessary. To secure a firm canthus two double-needled sutures of No. 4 silk are passed through the skin of the upper pillar of the old canthus and brought out through

the raw surface of the pillar; they are again reunited into the raw surface of the lower pillar, and made to issue upon the skin surface of that structure. They are then finally tied on two pearl buttons. The pedicle of the flap is then buried under this bridge of tissue, and unless the tension upon the pillars is too great, which may be avoided by a careful dissection of the tissues of the canthal pillars prior to inserting the sutures, union is prompt and satisfactory. Should the tissues give way, the canthus may be restored later, after the flaps have united, by excising a diamond-shaped area of skin from the pedicle of the flap and uniting the edges of the denuded area in the manner just described (Fig. 306, *A*, *B*, *C*, *D*). (See also p. 299, "Esser's epithelial inlay.")

Plastic Operations of the Eyelids (Blepharoplasty*).—Much can be accomplished in the early treatment of wounded and lacerated eyelids and their surroundings, and thus prevent the subsequent deformities and contractions. Scrupulous aseptic cleansing of the injured areas is of paramount importance, and as Major H. Delp Gillies well maintains, all tissue should be retained the retention of which is feasible; it should be put back into its normal place at as early a date as possible. Stitches must be neatly inserted and with due regard to a coaptation of the lacerated parts in their proper positions. Had such "early treatment" always been possible, and always when possible been carried out intelligently, much subsequent plastic surgery might have been avoided in many of those wounded in war.

Moreover, before attempting the correction of lid deformities it is important to eliminate sources of infection in their neighborhood; suppuration of the conjunctival mucous membrane by suitable antiseptic irrigation; pus in the lacrimal sac by its excision; and purulent secretion of the ethmoid, frontal, and antral sinuses.

In general terms, lid deformities may be corrected by grafting (Wolff-Lefort flaps or Thiersch grafts), by the use of pedunculated flaps, by excision of a **V**-shaped piece of the lid (Adams' operation†), or the V Y operation (Wharton Jones' operation‡), by the Esser epithelial inlay, and the Gillies epithelial outlay. Neither Adams' nor the V Y operation, although occasionally useful, as a rule meet the indications for correction presented by ectropic conditions, hence the chief reliance must be placed on the other methods briefly summarized.

Whether pedunculated flaps or other forms of skin-grafts shall be employed must be decided by the operating surgeon, according to his experience, and this is true as to whether a Thiersch or a Wolff graft

* Plastic operations on the eyelids have necessarily greatly increased in number as the result of war injuries. In many instances the operation is not alone concerned with the eyelids, but owing to extensive or multiple wounds is concerned with the larger problems of maxillofacial surgery, and therefore the plastic surgeon and the ophthalmologist may often find it of advantage to work together. Operations on the eyelids, including description of some of the formal procedures of blepharoplasty, are described in Vol. IV, pp. 915–922. The present paragraphs are intended as a supplement. They should also be read in connection with the chapters by Darcissac and Harte and Lee on Fractures of the Jaws.

† Consult Fig. 487, p. 918, Vol. IV.

‡ Consult Fig. 489, p. 919, Vol. IV.

shall be used. Personally, our experience and observation have been most favorable to the various methods of grafting, not, however, to the exclusion of pedunculated flaps, which in certain cases not only produce the desired cosmetic effect, but are essential.

Absence of the action of the elevator of the lid and loss of the lid margin of the upper lid present complications which preclude in most instances a satisfactory result; indeed, in these circumstances Gillies considers operation practically useless, that is, operation on the lids and orbital socket, and he doubts if a strip of eyebrow, although it has often been used, constitutes a satisfactory replacement of the eyelashes when the margin of the upper lid has been lost. Dr. John Wheeler, however, has designed an operation for such conditions which has achieved good results, and Morax has reformed eyebrows by transplants from the opposite brow or from the occipital region.

Operations for Ectropion.—In cases where the lid deformity is not too elaborate the following procedure may be put into operation:

The ectropionized lower lid, for example, is dissected free of attachments in such a manner that it can be drawn upward well over the upper lid and held in place by three sutures passed through a strip of firm zinc plaster fastened horizontally above the brow. All underlying cicatricial bands are divided and scarred tissue removed. The denuded area which presents itself is covered with a large Thiersch graft, which should be cut thin from the inner aspect of the arm, and which should be larger than the surface it covers, and be pressed neatly and smoothly into position. No dressing of any kind should be placed on the graft, but it should be exposed to the air, and even better, when possible, to the sunlight. At first there is considerable wrinkling of the Thiersch graft, but gradually this disappears and ultimately, in successful cases, the surface is smooth. The stitches are removed at the end of ten days or two weeks.

The tissue of the cheek below the area denuded by the dissection of the ectropionized lid may be supported, to prevent its sagging, by suitable strips of plaster. Naturally, the same procedure applies to an ectropion of the upper lid, which after being freed is drawn downward over the lower lid, and is fastened as before to the subjacent tissue of the cheek.*

In place of an epidermic (Thiersch) graft used in the manner just described, a whole-skin or dermic graft may be utilized, and in the opinion of many surgeons, especially Wheeler, constitutes the most satisfactory operation for the relief of *cicatricial ectropion.* The bed for the graft is prepared by making an incision a few millimeters from the margin of the lid (usually it is the lower lid) as long as the palpebral fissure, followed by a dissection which removes *all* of the scar tissue, sparing the muscle as much as possible. Next the upper and lower eyelids (if the eyeball is in place) are sewed together at three equidistant points after freshening their margins at the points of con-

* The cutting of a Thiersch graft is materially facilitated if, according to W. R. Parker's suggestion, the prepared skin is first greased with sterilized vaselin.

tact and put on the stretch by means of strips of adhesive plaster placed above and below. The whole-skin (dermic) graft, one-third larger than the defect it is intended to cover, is now taken from the inner side of the arm and transferred to the denuded area and stitched neatly into place. The graft is lightly smeared with sterilized vaselin or White's ointment, then covered with thin rubber tissue on which is placed a layer of surgical gauze, and the whole held in place with a compressing bandage over an even layer of surgical cotton. The dressing should not be disturbed for at least four days.

In order to understand Gillies' operation for ectropion it is necessary to describe "*Esser's epithelial inlay*," designed by this surgeon for the cure of entropic conditions of any mucous orifice, and therefore also to remedy turned-in lids and to enlarge contracted orbital sockets. For the relief of the last-named conditions it is, quoting Major Gillies' description, performed as follows:

Esser's Inlay.—"To enlarge the lower fornix an incision is made from the outside into the lower lid until the deep surface of the conjunctiva is reached. The scar tissue which is found in this situation, due to the injury, is next dissected carefully off the deep surface of the conjunctiva; some sterilized dental composition is then taken, and the mold of this cavity prepared. The skin edges are drawn together over the mold in order to ascertain whether it is of the right size. If it is too big, it is cut down until the skin edges meet. The mold is next taken out of the cavity and a freshly cut Thiersch graft from the inner side of the arm is wrapped around the mold, which is put into the cavity, the epithelial surface of the graft being toward the mold. The skin edges are next united over the mold and skin-graft, which should be buried for ten days.

"At the end of this time an incision is made through the conjunctiva at the spot where the scar tissue was removed. Immediately underlying the conjunctiva will be found the skin-graft, and next to it the mold. One blade of a pair of scissors is inserted into the cavity in which the mold is lying, and the incision in the conjunctiva thus widened to the full extent of the size of the mold. The mold can be easily removed, and it will be found that the cavity in which it is lying is epithelialized on all its aspects, and the only raw surface to contend with is the small area lying between the skin-graft and conjunctiva. A prosthetic piece should be immediately inserted into the cavity to retain its size and shape and to keep its opening into the eye socket widely patent. This is of great importance, and the nearer the inlay is put to the conjunctiva in the first instance, the less raw area there is to heal over."

Epithelial Outlay for the Correction of Ectropion (Gillies' Operation).—Using Esser's inlay operation as a basis, Gillies has developed a method by which the skin surface of an eyelid is so augmented as to correct the ectropion. His procedure, quoting his own description, is as follows:

"For ectropion of the upper lid a curved incision is made just above

the lid margin. This is deepened slightly, but not down to the tarsal plate, and care is taken to avoid interference with the levator palpebræ superioris muscle. To a certain extent the flap of skin lying above the incision between the incision and the eyebrow is undercut. This undercutting is continued until the lid margin descends to a lower level than normal.

"A mold is next taken of this cavity, covered with skin-graft in the same way, and the skin united again at the original incision. After the skin is thus sewn over the mold the ectropion is more pronounced for the time being and until the mold is removed. This incision is not tightly closed, so that there are one or two gaps in it which allow the new epithelium to grow around the margin of the incision. In some of the cases the incision is reopened and the mold removed on the tenth day. The lid will drop below the normal level, and the ectropion is permanently cured. In other cases the incision is allowed to open gradually of its own accord, until there are only one or two small bridges of skin holding it in position. These can easily be cut."

Pedunculated Flaps.—For the repair of displaced eyelids and loss of lid substance pedunculated flaps taken from the temple and forehead and rotated into place after suitable dissection are constantly utilized, and in the opinion of many surgeons the flap method should generally be the operation of election. So also the flap may be cut from the cheek and slid or advanced into position to cover the raw surface which has been exposed by the dissection made necessary to return the displaced lid to its normal relations. (Compare Fig. 490, Vol. IV.)

Naturally, retractions of the temporal portions of the lids are more easily remedied than those of the nasal aspect. But small flaps cut from the forehead and turned down to correct defects near the inner canthus can be utilized, as especially recommended by T. Harrison Butler.

Some of the well-known flap operations to repair lid displacement and loss of lid substance are described and figured in Vol. IV, p. 919, but each case must be studied and the plan of procedure decided by the conditions present. Space does not permit a description of the many ingenious plastic methods devised especially during the recent war. Certain general principles may be mentioned:

The exposed raw surface should be carefully measured with compasses or a template made of tinfoil or rubber tissue, to guide the surgeon in marking out the flap which is to be rotated or advanced into position. Cicatricial tissue must be entirely removed and cicatricial bands thoroughly divided. Ligation to control hemorrhage should be avoided; during operation pressure and artery clamps should be used to control bleeding, and the vessels twisted before the hemostats are removed. Captain John Wheeler suggests that a small gauze drain, to remain a day or two, should be placed at or near the base of the flap. Support of flaps in order to avoid tension may be secured with properly placed strips of plaster, and Wheeler employs adhesive strips, equipped with small hooks, so placed that the proper traction will be produced

to give relaxation to the flap. A rubber band is strung between the hooks to produce tension. Although skin sutures may be removed in four to five days, this relaxation apparatus should remain in place for at least ten days to assure strong union, with the eyelid in proper position (Wheeler) (Fig. 307).

In a certain number of cases a cavity is formed because there has been a depressed adherent flap. This may be filled in with fat or muscle before the flap is sutured into place, and loss of a portion of the orbital margin may be repaired by cartilage grafts.

Should it not be possible to cover in completely the defect on the temple, cheek, or forehead after the flap has been rotated into place, the defect may be covered with a Wolff or Thiersch graft.

FIG. 307.—SUPPORT OF FLAP, AS UTILIZED BY CAPTAIN JOHN WHEELER. ("Archives of Ophthalmology.")

Should there be breaking down of the epithelium of the flaps, indicating necrosis of the upper layers, the suggestion of Gifford to scrape the area until healthy bleeding tissue is reached, and then apply a Thiersch graft, may be followed with advantage, although the necessity for this is more likely to occur in cases in which a flap without a pedicle has been transplanted than where flaps retain living connection with the surrounding tissues.

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CHAPTER XL

DIRECT LARYNGOSCOPY, BRONCHOSCOPY, AND ESOPHAGOSCOPY

By Chevalier Jackson, M. D., F. A. C. S.,
Philadelphia, Pa.

Direct laryngoscopy, bronchoscopy, and esophagoscopy are procedures in which, by means of electrically lighted tubular specula, the interior of the lower air passages and the esophagus instead of being seen in a reflecting mirror are brought into direct view for the diagnosis and treatment of diseased conditions or the removal of foreign bodies. These procedures when carefully and skilfully done are devoid of harm; but the art is a gentle one and requires a fundamental knowledge of the endoscopic anatomy, a certain amount of manual dexterity, a properly arranged technic, training of the eye to work through a long tube and of the brain to work with one eye only, and a definite visualization of the mechanical problems involved. The training of the eye to gage depth and to recognize landmarks is best done by simulating foreign body problems in a soft-rubber tube, one end of which is anchored with a weight, the bronchoscope being inserted into the other end. If the foreign body cannot be disimpacted and removed from the rubber tube it is self-evident that no attempt should be made on the living patient without further practice. It should be our aim so to perfect our technic and manipulations that all time-wasting delays or hesitation be eliminated during the endoscopy, for it has been repeatedly proved that prolonged endoscopies are dangerous, while short ones are free from mortality if carefully done. In the last 700 cases of bronchoscopy and esophagoscopy in my own clinic no death has resulted from the insertion of an endoscopic tube.

Instruments.—The instruments required for routine work are neither very numerous nor complicated. It is necessary, however, that the armamentarium be complete, for makeshifts are here impossible; the tubes used must be slightly smaller than the caliber of the smallest part of the natural passages to be examined. Dilatation of the natural passages is not possible here as in the urethra; any attempt to use an oversized tube in the trachea, bronchi, or esophagus is quickly and inevitably fatal. The instruments shown in Fig. 308 are those in common use. The different sized tubes are not shown. An ordinary working outfit consists of the following instruments:

One Jackson's adult laryngoscope.
One Jackson's child laryngoscope.
One Jackson's infant diagnostic laryngoscope.
One Jackson's anterior commissure laryngoscope.

One Jackson's bronchoscope, 4 mm. x 30 cm.
One Jackson's bronchoscope, 5 mm. x 30 cm.
One Jackson's bronchoscope, 7 mm. x 40 cm.
One Jackson's bronchoscope, 9 mm. x 40 cm.
One Jackson's esophagoscope, 7 mm. x 45 cm.
One Jackson's esophagoscope, 10 mm. x 53 cm.
One Jackson's side grasping forceps, extra light, 40 cm.
One Jackson's forward grasping forceps, regular, 50 cm.
One Jackson's forward grasping forceps, regular, 60 cm.
Six Jackson's endoscopic sponge carriers.
One Jackson's aspirator with double tube for minus and plus pressure.
One Jackson's aspirating nozzle for mouth secretion.
One Jackson's double circuit bronchoscopy battery.
Four rubber-covered conducting cords for battery.
One box Jackson's bronchoscopic sponges, size No. 4.
One box Jackson's bronchoscopic sponges, size No. 5.
One box Jackson's bronchoscopic sponges, size No. 7.
One box Jackson's bronchoscopic sponges, size No. 10.
One McKee-McCready bite block, adult's size.
One McKee-McCready bite block, child's size.
One laryngeal grasping forceps.
One dozen extra lamps for lighted instruments.

Anesthesia.—In my own Jefferson College clinic neither general nor local anesthesia is used in endoscopy on children. To lessen the cough reflex and apprehension in the older children paregoric, or a small amount of morphin guarded with atropin, is sometimes helpful. In adults no anesthetic or sedative is required for esophagoscopy or diagnostic laryngoscopy. For laryngeal operations and bronchoscopy in adults a preliminary hypodermic injection of morphin with atropin is given one hour before operation. At the time of operation 5 per cent. cocain solution is applied to the pharynx with a gauze sponge on a sponge-carrier. The larynx is then exposed with the laryngoscope and its interior anesthetized by the gauze sponge application of a 20 per cent. cocain solution; if the procedure be a bronchoscopy, deeper applications of the same strength are made by inserting the saturated gauze sponge on the long carrier (Fig. 308, *K*) through the glottis down to the bifurcation. After introducing the bronchoscope the deeper parts may be anesthetized in the same manner. It deserves repetition that the use of cocain applies to adults only.

An inexperienced operator will find general anesthesia of great assistance; so that the matter of general anesthesia must be decided by the personal equation of the operator in the particular case. It should be kept in mind, however, that dyspnea is a contraindication to general anesthesia.

Asepsis.—Complete aseptic operating-room technic should be observed in all endoscopic procedures; for while the patient may be immune to the bacteria he himself harbors, the introduction of other strains may set up virulent infections. Furthermore, diphtheria, lues, tuberculosis, and other specific infections are so frequently encountered in endoscopic work that the conscientious surgeon will find the simplest way is to carry out the regular operating-room technic. Oral antisepsis preliminary to operation is best practised by the use of alcohol (20 per cent.) as a mouth-wash and gargle. It has been repeatedly demon-

strated that the bronchoscope introduced by my own technic is free from the probability of carrying infection from the mouth to the deeper air passages.

Position of the Patient.—In any peroral endoscopic procedure the position of the patient is of fundamental importance. The patient is

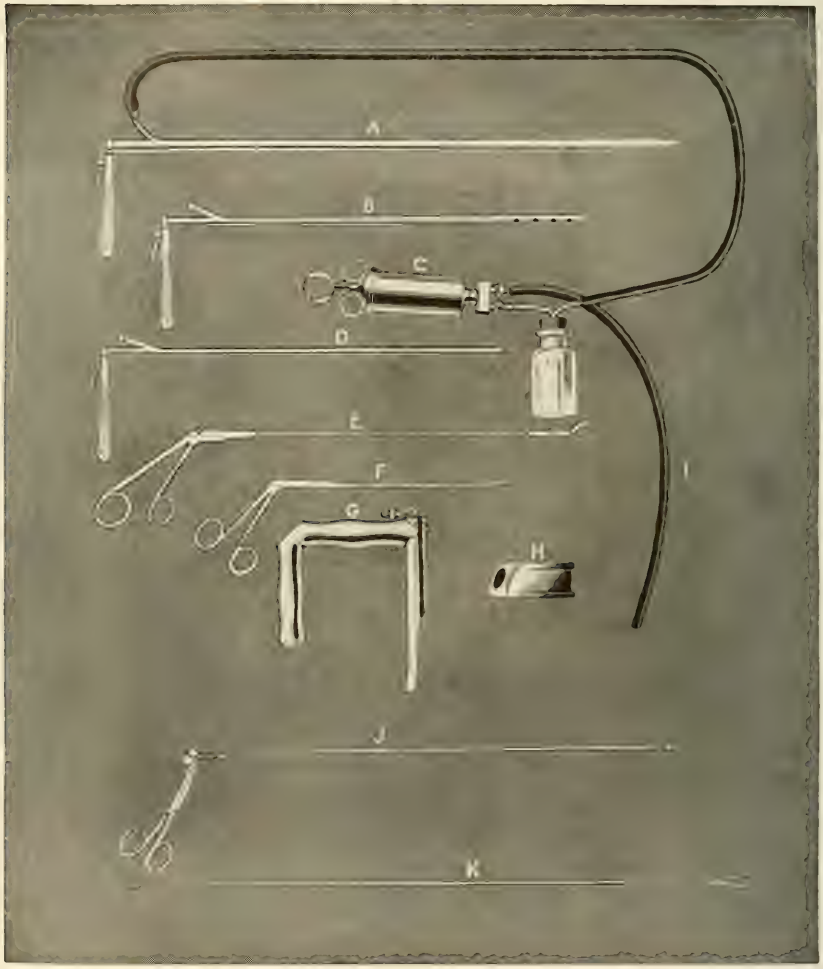

FIG. 308.—CHEVALIER JACKSON'S INSTRUMENTS FOR DIRECT LARYNGOSCOPY, BRONCHOSCOPY, AND ESOPHAGOSCOPY.

A, Gastroscope with aspirator attached; *B*, bronchoscope; *C*, aspirator with negative pressure tube attached to gastroscope. Positive pressure tube *I*; *D*, esophagoscope; *E*, laryngeal cutting forceps for taking specimens; *F*, laryngeal grasping forceps; *G*, adult size laryngoscope; *H*, bite-block; *I*, positive pressure tube from aspirator; *J*, forceps for removing foreign bodies; *K*, sponge-carrier for sponging the field and obtaining specimens of secretion from the bronchi.

recumbent for better control and ease of manipulation of the head and shoulders. For direct laryngoscopy the patient's head is upon the table; but when direct laryngoscopy is done as a preliminary to bronchoscopy the patient's head and shoulders should be out in the air, as shown in

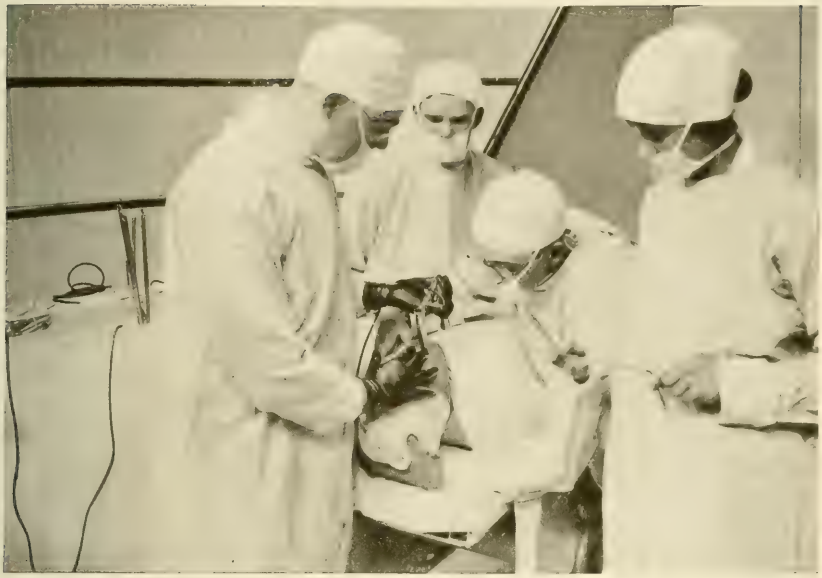

FIG. 309.—DIRECT LARYNGOSCOPY, RECUMBENT PATIENT.

The assistant holding the head is standing. His left hand is producing extension on the occipito-atloid joint and at the same time raising the occiput above the level of the table. The bite-block is inserted in the left corner of the mouth, being held on the right thumb of the assistant, the palm of the hand and the extended fingers resting on the patient's left cheek to prevent rotation of the head.

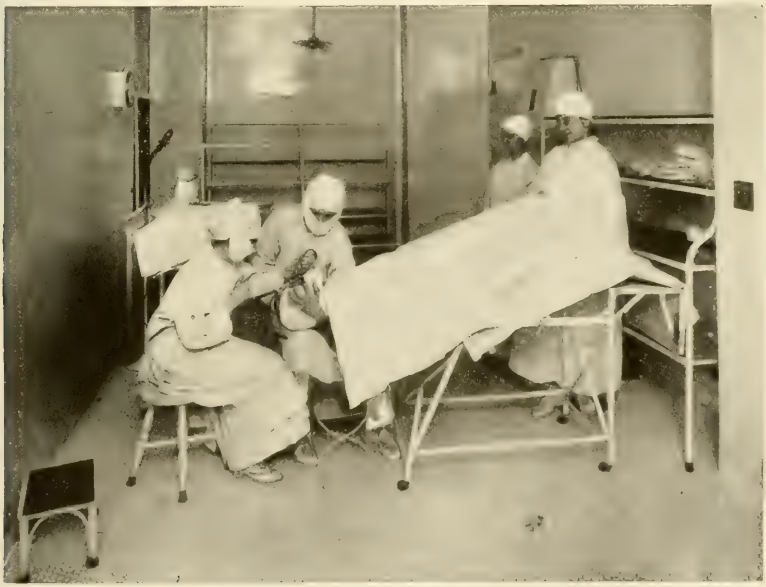

FIG. 310.—AUTHOR'S POSITION OF THE PATIENT FOR THE REMOVAL OF FOREIGN BODIES FROM THE LARYNX OR FROM ANY OF THE UPPER AIR OR FOOD PASSAGES.

If dislodged, the intruder will not be aided by gravity to reach a deeper lodgment.

Fig. 313, in order to permit of free motility of the head and neck in every direction as required in the exploration of the deeper air and food passages with a straight and rigid endoscopic tube. Some extension of the head is necessary to move the upper teeth out of the way, but the extension must be strictly limited to the occipito-atloid joint. If the extension includes all of the cervical vertebræ, as in the Rose position, the introduction of an endoscopic instrument will be exceedingly difficult. Another important difference from the Rose position is that for endoscopy it is essential that the head be held very high. The occiput should be higher than the level of the table during the start of introduction. When the tube has reached the deeper passages the head may be moved in any direction required by the operator who is following the lumen as it opens up ahead of the endoscopic tube. The position given in Fig. 309 has been worked out by long experience to facilitate the introduction of the tube and to prevent fatigue of the assistant who holds the head. The only exception to this position is in case of a foreign body lodged in the larynx or pharnyx, in which it is very necessary to avoid the dropping of the intruder into the deeper air passages in case the foreign body should be dislodged and not firmly grasped. The proper position for such cases is illustrated in Fig. 310.

LARYNGOSCOPY

Direct laryngoscopy is so called in distinction from indirect or mirror laryngoscopy. The patient being in the position shown in Fig. 309 (or in case of a foreign body in the larynx, in that shown in Fig. 310), the laryngoscope is grasped in the left hand as shown in Fig. 311. The fingers of the operator's right hand are used to draw out of the way the upper lip of the patient lest the upper lip get pinched between the instrument and the upper teeth. Such an accident will cause the patient exquisite torture, whereas if pinching the lip be avoided there is nothing in the other part of the procedure that will be painful. The introduction of the laryngoscope and the exposure of the larynx may, for clearness of description as well as for promptness and effectiveness of execution, be divided into two stages:

1. Exposure and identification of the epiglottis.
2. Elevation of epiglottis and all the tissues attached to the hyoid bone so as to expose the larynx to direct view.

The patient is told to open his mouth, or, in case of general anesthesia, the mouth is opened, and the bite block (Fig. 308, *H*) inserted between the teeth on the left side of the patient's mouth. The laryngoscope is passed into the patient's mouth along the right border of the dorsum of the tongue. When the posterior portion of the tongue is reached the spatular tip of the instrument is deviated toward the middle line so as to expose the epiglottis.

Second stage: The instrument is now passed about 1 cm. deeper, the spatular tip passing posterior to the epiglottis, and immediately a lifting action is exerted with the spatular tip, as if the effort were being made to suspend the head by lifting upon the hyoid bone with the

spatular tip of the instrument. If the larynx is not at once exposed it is probable that the instrument has been inserted too deeply. If so, a slight withdrawal is necessary to bring the epiglottis again into view, when the procedure of lifting is again exerted. Great care is necessary to avoid the great natural tendency of the operator unconsciously to lower his head and to get lower and lower himself. This must resolutely be resisted, and the object always kept in mind of *lifting* the patient's head and neck upward so that the operator can see into the larynx without bending over. In other words, lifting the laryngoscope up to a point where the operator's eye can see through it into the larynx. This is necessary to avoid the fundamental error of trying to pry open the larynx by using the upper teeth as a fulcrum. When the larynx first

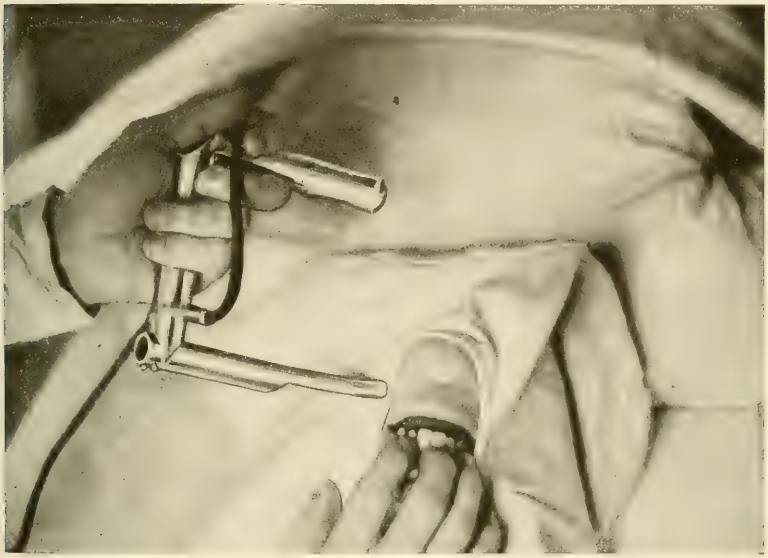

FIG. 311.—DIRECT LARYNGOSCOPY, RECUMBENT PATIENT.

The laryngoscope is held in the *left* hand. The first, second, and third fingers of the *right* hand are used to pull down the upper lip of the patient to prevent pinching the lip between the laryngoscope and the teeth. The camera being above the patient gives a false impression of the position of the head and chest. The chest is really very much lower than the head.

comes into view the chords are not visible because of the spasmodic, tight closure of the ventricular bands. The patient is told to take a deep breath. As soon as he does so, the glottis opens and the chords are visible on each margin. Of course, if the patient is under a general anesthetic he cannot be told to take a deep breath; but if he be so deeply anesthetized that the reflexes are abolished the glottis will be open.

Removal of Foreign Bodies from the Larynx by Direct Laryngoscopy.—Having exposed the larynx in the manner described, the foreign body is searched for, and when found, the portion of it to be seized is determined according to the size, shape, and surface of the foreign body. Pointed foreign bodies should always be seized at or as close to the point as possible and the point is then freed from the tissues

before removal. In the case of transfixed foreign bodies great care is necessary not to lacerate the larynx by pulling them out crosswise. They should be seized, as in the case of pointed foreign bodies, near one end if neither end be pointed. Foreign bodies in the subglottic space should be very carefully disimpacted and brought out with their greatest diameter corresponding to the sagittal plane. Great care should be taken not to lacerate the chords and not to injure the crico-arytenoid joint, either of which accidents may seriously impair the voice. Severe trauma may cause edema, later, perichondritis, either of which may cause so much stenosis as to require tracheotomy. Care in the manipulations will avoid such complications.

Direct Laryngoscopy for the Removal of Laryngeal Growths and Specimens.—For the differential diagnosis of diseases of the larynx, such as lues, malignancy, and tuberculosis, it is often necessary to remove a specimen of tissue for biopsy. For this purpose direct laryngoscopy is invaluable because of the accuracy with which the

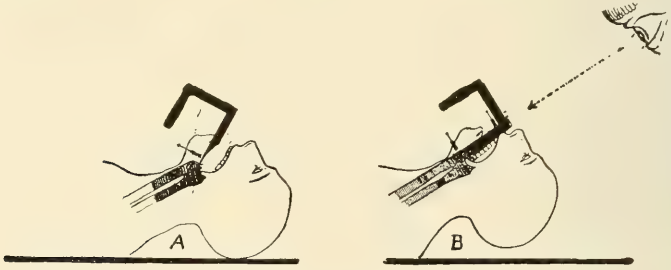

FIG. 312.—SCHEMA ILLUSTRATING MANNER OF EXPOSURE OF THE LARYNX WITH THE DIRECT LARYNGOSCOPE.

At *A* the laryngoscope has been inserted posterior to the dorsum of the tongue until the epiglottis has come into view. The laryngoscope is then inserted about 1 cm. deeper, the spatula tip going posterior to the epiglottis. A strong lifting motion is now exerted in the direction of the dart, even lifting the patient's head from the table as shown at *B*. The glottis and the tracheal axis are thus brought in line with the observer's visual axis.

specimen can be removed from precisely the location desired. It is advisable to remove the margin of the growth or ulcer so as to include a small portion of the normal mucosa in order that the histologist may see the transition. If the case prove to be one of malignancy, it is perhaps not so serious a matter if the voice be impaired; but if the case should prove to be one of tuberculosis or lues it is a misfortune to have injured the voice by damaging the chords or the motor area of the larynx. Therefore, whenever possible some area other than these should be selected for the removal of the specimen. For the removal of specimens the cutting forceps (Fig. 308, *E*) is the best.

The Removal of Benign Growths from the Larynx by Direct Laryngoscopy.—Benign growths such as papillomata can be removed with great accuracy by the direct method, and such removal usually results in a prompt restoration of the voice, if, as is usually the case, the growth has been interfering with clear phonation. The best forceps for this purpose is one having crushing jaws rather than cutting jaws,

because the papillomata are very small, resembling venereal warts in character. They are very readily crushed off, and the difference between the sound tissues and a papilloma is very promptly noticed by the trained touch. Since papillomata are very prone to recur, radical operation is contraindicated. It is very unwise to remove the base deeply. The recurrence is essentially different from the recurrence of malignancy. Papillomata do not infiltrate the basal tissues, and very often a "recurrence" is in the form of an entirely new growth in a new location. No matter how radically a papillomatous mass may have been removed from one chord, such removal can in no way prevent recurrence at another site, for instance, the opposite ventricular band, and to have damaged the chord by radical removal of the base is a great and avoidable misfortune. The best ultimate vocal results are obtained from very neatly and precisely removing the protruding portion of the papillomatous mass flush with the surface of the mucosa, with subsequent removal of "recurrences" as they appear, until the time arrives when the tendency to recurrence ceases. Ultimately, from many removals or from some other cause, the tendency to recur disappears. Benign growths other than papillomata usually do not recur after complete and precise removal by direct laryngoscopy.

Direct Laryngoscopy for the Introduction of Intratracheal Insufflation Anesthesia Tubes.—The insufflation catheter can be inserted in the trachea by anyone who will take the time to practice the details mentioned under the heading of Direct Laryngoscopy. The catheter could be introduced in any patient without either general or local anesthesia by those who have acquired the knack; but, inasmuch as the patient is to be anesthetized anyway, he should be placed *deeply* under the ether by the open method before any attempt is made to insert the insufflation catheter. This abolishes the laryngeal reflexes and relaxes the muscles of the neck in a way that makes it very easy to expose the larynx if the anesthetist follow the instructions as to *lifting* the patient's head off of the table by the hyoid bone with the tip end of the laryngoscope passed posteriorly to the epiglottis before the lifting motion is commenced, as seen in Fig. 312. The following rules should be carefully observed:

1. The patient should be fully under the anesthetic by the open method so as to get full relaxation of the muscles of the neck and abolition of the pharyngeal and laryngeal reflexes.

2. The patient's head must be in full extension, with the vertex firmly pushed down toward the feet of the patient, so as to throw the neck upward and bring the occiput down as close as possible beneath the cervical vertebræ; but it is essential to remember that the extension must be only at the occipito-atloid joint and that the patient's head must be lifted off the table. Extension with the head lower will mean a curvature of the cervical vertebræ which will defeat the object entirely. The head must be high.

3. No gag should be used, because the patient should be sufficiently anesthetized not to need a gag, and because wide gagging defeats the

exposure of the larynx by jamming down the mandible on to the hyoid bone and larynx.

4. The epiglottis must be identified before it is passed.

5. The laryngoscope must pass sufficiently far below the tip of the epiglottis so that the latter will not slip away.

6. Too deep insertion must be avoided, as in this case the laryngoscope goes posterior to the cricoid, and the cricoid is lifted, exposing the mouth of the esophagus, which is bewildering until sufficient education of the eye enables the operator to recognize the landmarks.

7. The size of the silk woven catheter must be in proportion to that of the glottis. A No. 24, French scale, catheter will comfortably fit in an adult larynx and allow free return flow through the larynx; correspondingly smaller tubes are to be used for younger cases.

BRONCHOSCOPY

Introduction of the Bronchoscope.—The essentials for the quick and skilful introduction of the bronchoscope are two, namely:

1. Adequate exposure of the glottis by direct laryngoscopy.
2. Correct position of the patient.

FIG. 313.—THE OPERATOR IS LIFTING UPWARD STRONGLY WITH THE LARYNGOSCOPE AS THOUGH SUSPENDING THE HEAD AND NECK STRUCTURES BY THE HYOID BONE.

Care should be taken not to use the teeth as a fulcrum and try to expose the larynx by wedging the tip of the laryngoscope upward. The bronchoscope is about to be introduced. Note the position of the handle toward the right.

With practice it should not require more than from thirty to fifty seconds to introduce the bronchoscope in any patient whose mouth can be opened, and this can be done in children without any anesthesia, general or local. In adults introduction need require no longer except for the time consumed in the painting on of a local anesthetic. The

glottis having been exposed in the manner described under Direct Laryngoscopy, the bronchoscope, illuminated with its own separate cord from the bronchoscopic battery, is introduced into the laryngoscope. The bronchoscopist's eye is now transferred to the bronchoscope and the glottis found again. The bronchoscope must always be introduced in the position shown in Fig. 314, the handle being out to the right, as shown at *H*. As soon as the bronchoscopic tube mouth has entered the trachea care is taken to be sure that the bronchoscope is introduced not farther than 3 cm. The heavy laryngoscope is then removed by axially rotating it sidewise and removing the slide, leaving

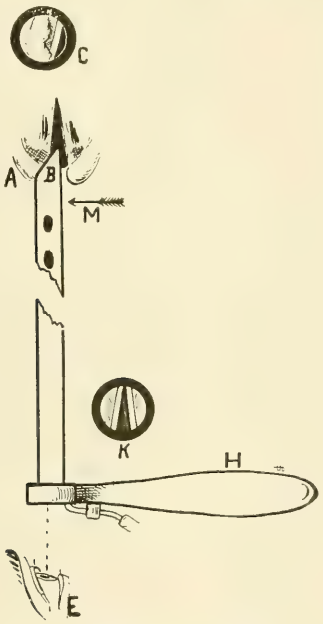

FIG. 314.—SCHEMA ILLUSTRATING THE INTRODUCTION OF THE BRONCHOSCOPE THROUGH THE GLOTTIS, RECUMBENT PATIENT.

The handle, *H*, is always horizontally to the right. When the glottis is first seen through the tube it should be centrally located as at *K*. At the next inspiration the end, *B*, is moved horizontally to the left as shown by the dart, *M*, until the glottis shows at the right edge of the field, *C*. This means that the point of the lip, *B*, is at the median line and it is then quickly (not violently) pushed through into the trachea. At this same moment or the instant before, the hyoid bone is given a quick additional lift with the tip of the laryngoscope. In the sitting patient everything is the same except that the laryngeal image is reversed sagitally and laterally.

only the light bronchoscopic tube in position, as shown in Fig. 313. Before removing the laryngoscope, however, it is necessary to be certain that the bronchoscope is in the trachea. There are times when the bronchoscope seems to have a tendency to slip into the esophagus. The identification of the trachea is very readily done when the trachea is not inflamed, because the rings show very clearly. If the mucosa is edematous, the rings may be obliterated. A strong blast of air usually comes up through the bronchoscope in an unmistakable way, but it must be remembered that the bronchoscopist may be deceived by the "breathing" of the esophagus apparent when a tube is inserted in it

owing to the alternate negative pressure during inspiration. This breathing, however, is usually associated with a bubbling, fluttering sound that is unmistakable once it is heard. Further identification of the trachea is afforded by the recognition that the tube stands open, whereas the esophageal image is more or less made up of collapsing folds. In the exploration of the tracheobronchial tree the next landmark is the bifurcation of the trachea, which is located by "weaving" the bronchoscope from side to side. This lateral motion is necessary because the bronchoscope is necessarily much smaller in diameter than the trachea. If it were not, it could not enter either bronchus. Usually it is better to have the patient's head a little to the right and the handle (Fig. 314, *H*) drawn over to the right. This brings more naturally into view the

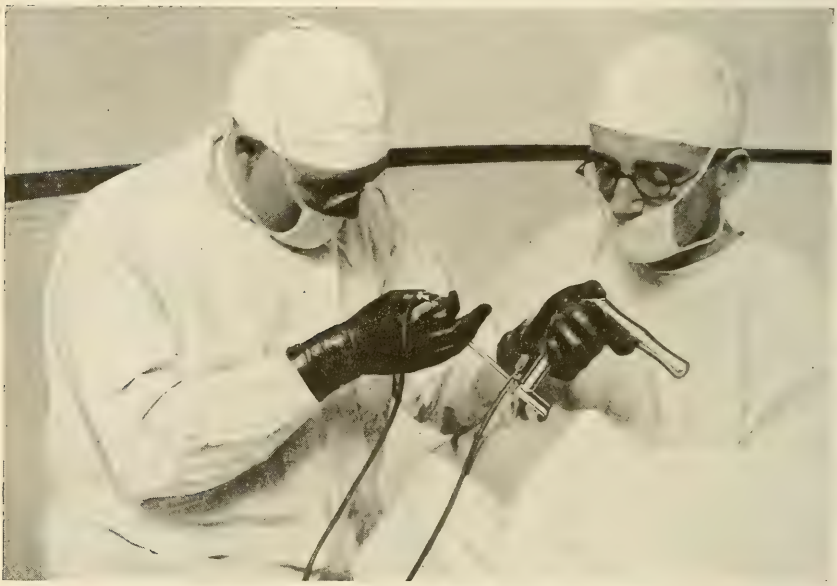

FIG. 315.—INSERTION OF THE BRONCHOSCOPE.

Note direction of the trachea as indicated by the bronchoscope. The patient's head is held above the level of the table. The assistant's left hand should be at the patient's mouth holding the bite-block. This is removed and the assistant is on the wrong side of the table in the illustration in order not to hide the position of the operator's hands. Note the handle of the bronchoscope is to the right.

left bronchial orifice. Needless to say it is necessary to see both bronchial orifices in order to see the bifurcation between them, because morphologically the right bronchus is the normal continuation of the trachea, and the bronchoscope goes on down into it without the observer's having seen the left bronchial orifice at all, unless particularly searched for. Having located the carina,* the *right upper lobe bronchus* is next to be exposed. This is done not by deeper insertion of the bronchoscope, but simply by the strong swinging of the head to the left with the bronchoscopic tube mouth at the carina. The upper lobe bronchus is given off practically at the bifurcation so far as endoscopic appearances are concerned. The next important landmark is the *middle*

* The ridge between the right and the left bronchial orifice.

lobe bronchus which is seen by turning the handle (*H*) upward, so as to bring the lip (*B*) upward, the patient's head at the same time being dropped. This brings into view the anterior wall of the stem bronchus. The middle lobe bronchus comes off anteriorly and the *spur between the middle lobe bronchus and the inferior lobe bronchus* is a horizontal one. The stem bronchus below the middle lobe bronchus will be seen to give off dorsal and ventral as well as lateral branches. Returning to the carina, which is our first landmark in the lower air passages, the bronchoscopic lip is turned to the left, the patient's head moved over to the right, and the bronchoscope inserted into the *left main bronchus*. The

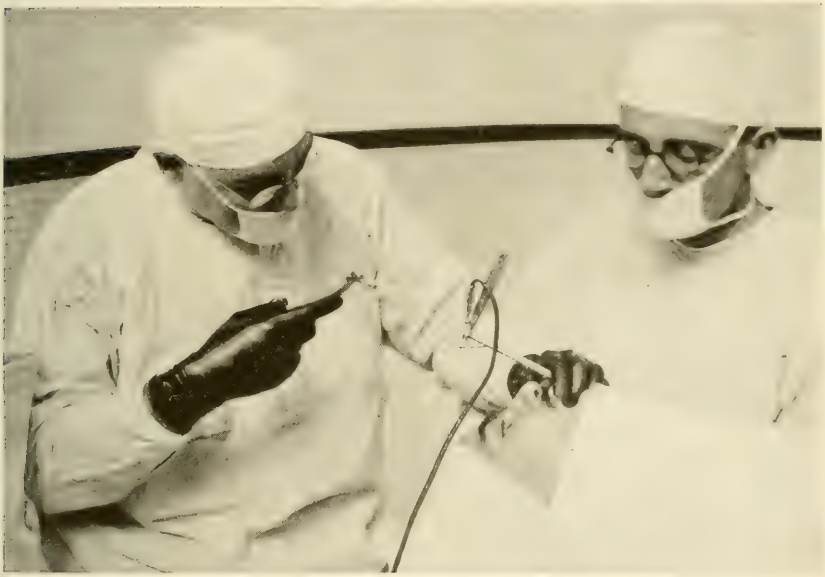

FIG. 316.—THE HEAVY LARYNGOSCOPE HAS BEEN REMOVED, LEAVING THE LIGHT BRONCHOSCOPE IN POSITION. THE OPERATOR IS INSERTING FORCEPS.

Note how the left hand of the operator holds the tube lightly between the thumb and first two fingers of the left hand, while the last two fingers are hooked over the upper teeth of the patient "anchoring" the tube to prevent it moving in or out or otherwise changing the relation of the distal tube-mouth to a foreign body or a growth while forceps are being used. Thus, also, any desired location of the tube can be maintained in systematic exploration. The assistant's left hand is dropped out of the way to show the operator's method. The assistant during bronchoscopy holds the bite-block like a thimble on the index-finger of the left hand, and the assistant should be on the *right* side of the patient. He is here put wrongly on the left side so as not to hide the instruments and the manner of holding them.

left upper lobe bronchus in the adult is given off about 2 to 3 cm. down from the carina. The orifice is exposed by strongly bending the head and neck of the patient to the right. The left upper lobe bronchus does not go off directly laterally, but somewhat anteriorly, so that the spur between it and the orifice of the inferior lobe bronchus is at an angle of about 45 degrees with the horizontal. The *left inferior lobe bronchus* gives off dorsal and ventral branches very similar to those on the right side except for the *one large posterior branch*, which is very frequently invaded by foreign bodies. The upper lobe bronchi on either side cannot be entered so as to present a lumen image. Only the orifices and a small portion of the lumen of the branch bronchi below can be

seen. The main portions of the upper lobe bronchi are "around the corner." Fortunately, they are exceedingly rarely invaded by foreign bodies; otherwise bronchoscopic removal would not be so uniformly successful.

Bronchoscopy for Disease.—Pulmonary abscesses can be entered with the bronchoscope and drained. In case of abscesses secondary to foreign bodies a cure results almost invariably from the dilatation of the orifice of the abscess and the removal of the foreign body. In abscess of the lung due to other causes bronchoscopy has so little to offer that external operation should not be delayed if deemed advisable. Why this difference should exist remains to be investigated. Be the cause what it may, there can be no question as to the clinical facts. Of 36 cases of pulmonary abscess secondary to foreign body in my own clinic, 34 are alive and well today, with perfectly normal lungs, as the result of the peroral bronchoscopic removal of the foreign body. Bronchiectasis presents almost a parallel. Bronchiectatic conditions not due to foreign body have been treated by endobronchial lavage and local medication with a degree of success that indicates that further effort in this direction is well worth while. On the other hand, bronchiectatic symptoms in cases secondary to foreign body have totally disappeared following the removal of the foreign body in every case.*

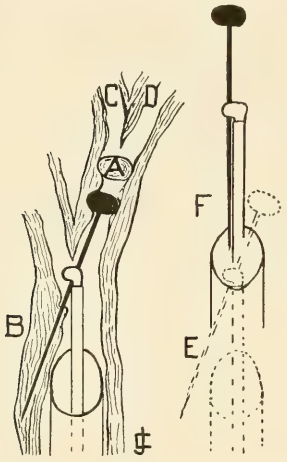

FIG. 317.—SCHEMA ILLUSTRATING THE MECHANICAL PROBLEM OF EXTRACTING A PIN, A LARGE PART OF WHOSE SHAFT IS BURIED IN THE BRONCHIAL WALL, *B*.

The pin must be pushed downward and if the orifice of the branches, *C*, *D*, are too small to admit the head of the pin, some other orifice (as at *A*) must be found by palpation (not by violent pushing) to admit the head, so that the pin can be pushed downward permitting the point to emerge (*E*). The point is then manipulated into the bronchoscopic tube-mouth by means of co-ordinated movements of the bronchoscopic lip and the side-curved forceps, as shown at *F*.

While the removal of esophageal secretion is readily accomplished by the drainage canal and negative pressure pump, it has been found the bronchial secretions are often too thick and viscid to pass readily through a drainage canal, which must necessarily be small. Because of this, I evolved the sponge-pumping system. This consists of inserting a properly sized and folded gauze sponge on a long Coolidge sponge-carrier through the bronchoscope so that it emerges from the distal tube mouth. The patient is then asked to cough, following which the sponge-carrier is withdrawn, bringing with it the secretion which the patient has coughed into the tube.

Bronchoscopy for Foreign Bodies.—The introduction of the bronchoscope may be very quickly mastered by anyone who cares to

* Chevalier Jackson: Bronchiectasis and Bronchiectatic Symptoms Due to Foreign Bodies, Penna. Med. Jour., vol. xix, Aug., 1916, pp. 807–814.

devote the necessary time to the manual practice of the details of introduction. When, however, we come to the mechanical problems of the withdrawal of a foreign body we have a totally different matter. The most intricate and involved mechanical problems may try to the

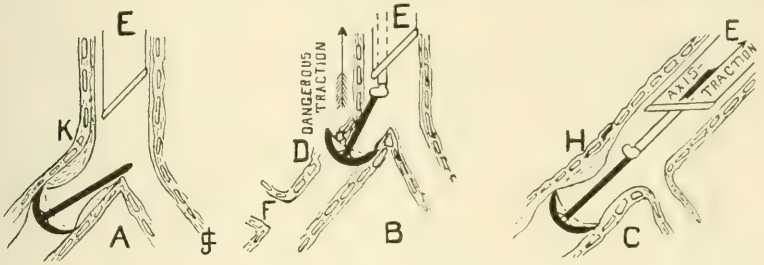

Fig. 318.—Schema Illustrating the "Mushroom Anchor" Problem of the Brass-headed Upholstery Tack.

At *A* the tack is shown with the head bedded in swollen mucosa. The bronchoscopist, looking through the bronchoscope, *E*, considering himself lucky to have found the *point* of the tack, seizes it and starts to withdraw it, making traction as shown by the dart in drawing *B*. The head of the tack catches below a chondrial ring and rips in, tearing its way through the bronchial wall (*D*) causing death by mediastinal emphysema. This accident is still more likely to occur if, as often happens, the tack-head is lodged in the orifice of the upper lobe bronchus, *F*. But if the bronchoscopist swings the patient's head far to the opposite side and makes *axis-traction*, as shown at *C*, the head of the tack can be drawn through the swollen mucosa without anchoring itself in a cartilage. If necessary, in addition, the lip of the bronchoscope can be used to repress the angle, *K*, and the swollen mucosa, *H*. If the swollen mucosa, *H*, has been replaced by fibrous tissue from many months' sojourn of the tack, the stenosis may require dilatation with the divulsor.

utmost the technical and especially the mechanical skill as well as the patience of the bronchoscopist. It is only by the greatest carefulness that trauma can be prevented, and it is only by the manipulation of the foreign body in such a way that points will not become entangled

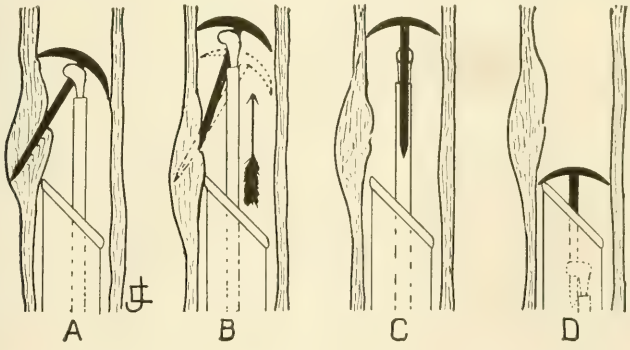

Fig. 319.—Problem of the Upholstery Tack with Buried Point.

If pulled upon, the imminent perforation of the mediastinum, as shown at *A*, will be completed, the bronchus will be torn and death will follow even if the tack be removed, which is of doubtful possibility. The proper method is gently to close the side curved forceps on the shank of the tack near the head, push downward as shown by the dart, in *B*, until the point emerges. Then the forceps are *rotated* to bring the point of the tack away from the bronchial wall. It is usually better at this stage to release the tack and grasp it firmly near the point for withdrawal, *D*. During stages *A*, *B*, and *C* the tack is grasped very gently.

in branch bronchi or buried in the mucosal wall that fatal trauma can be avoided. It is absolutely unjustifiable to seize and grasp any portion of a foreign body as soon as seen. The situation of the intruder must be studied and the proper position for the application of the

forceps determined. All of this must be done without delay, since prolonged bronchoscopies in children are exceedingly dangerous. For the successful solution of these complicated mechanical problems it is absolutely essential that the bronchoscopist shall practice long and carefully in a rubber tube so as to develop to the utmost the fine manual

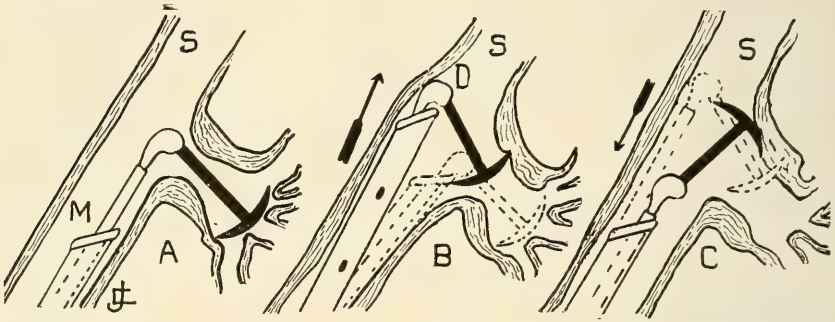

FIG. 320.—SCHEMA ILLUSTRATING THE "UPPER-LOBE BRONCHUS PROBLEM," COMBINED WITH THE "MUSHROOM-ANCHOR" PROBLEM AND THE AUTHOR'S TWICE SUCCESSFUL METHOD FOR THEIR SOLUTION.

The patient being recumbent, the bronchoscopist looking down the right main bronchus, *M*, sees the point of the tack projecting from the right upper-lobe-bronchus, *A*. He seizes the point with the side-curved forceps; then slides down the bronchoscope to the position shown dotted at *B*. Next he pushes the bronchoscopic tube-mouth downward and medianward, simultaneously moving the patient's head to the right, thus swinging the bronchoscopic level on its fulcrum, and dragging the tack downward and inward out of its bed, to the position, *D*. Traction, as shown at *C*, will then safely and easily withdraw the tack. A very small bronchoscope is essential. The *lip* of the bronchoscopic tube-mouth must be used to pry the forceps down and over, and the lip must be brought close to the tack just before the prying-pushing movement, *S*, right stem-bronchus.

skill by which he is able to execute exceedingly complicated manipulations by co-ordinate control of the lip of the tube mouth and the forceps. He soon acquires a habit of using these together just as one uses a knife and fork. He can turn a foreign body around end for end, doing a "version"; an unfavorable presentation can be converted into a favorable one for seizure; the lip can be used to make counterpressure upon

FIG. 321.—SCHEMA ILLUSTRATING THE ENDOSCOPIC CLOSURE OF OPEN SAFETY-PINS LODGED POINT UPWARD.

The closer is passed down under ocular control until the ring, *R*, is below the pin. The ring is then erected to the position shown dotted at M, by moving the handle, *H*, downward to *L* and locking it there with the latch, *Z*. The fork, *A*, is then inserted and, engaging the pin at the spring loop, *K*, the pin is pushed into the ring, thus closing the pin. Slight rotation of the pin with the forceps may be necessary to get the point into the keeper.

the tissues while the forceps is disembedding the point of a foreign body. All of these procedures can be done with perfect safety to the patient provided the bronchoscopist has deemed it worth while to practice the procedures and provided the time limit of the first bronchoscopy is not exceeded. Even the specialist in bronchoscopy does not get sufficient practice upon patients, because his bronchoscopies,

in each case, are usually limited to only the few minutes usually necessary to remove the foreign body. It is, therefore, necessary for everyone to educate the eye and the fingers by work with the bronchoscope, manipulating and removing a foreign body previously inserted in a

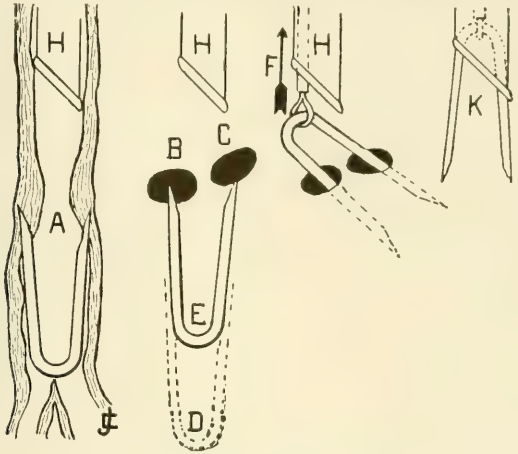

FIG. 322.—SCHEMA ILLUSTRATING A NEW METHOD OF REMOVAL OF BRONCHIALLY LODGED STAPLES OR DOUBLE-POINTED TACKS.

H, Bronchoscope. *A*, Swollen mucosa covering points of staple. At *E* the staple has been manipulated upward with bronchoscopic lip and hooks until the points are opposite the branch bronchial orifices, *B*, *C*. Traction being made in the direction of the dart (*F*), by means of the rotation forceps, the counterpressure being made with the bronchoscopic lip on the points of the staple, the points enter the branch bronchi and permit the staple to be turned over and removed with points trailing harmlessly behind (*K*).

piece of rubber tubing which serves as a manikin. In it all sorts of mechanical problems can be simulated. (A few of the solutions of mechanical problems are illustrated in Figs. 317–323 inclusive.) In all of these manipulations it is necessary to keep in mind that if no harm is

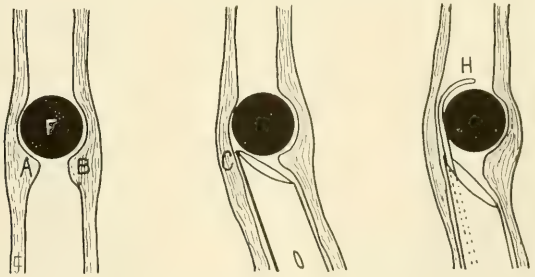

FIG. 323.—SCHEMA ILLUSTRATING THE USE OF THE LIP OF THE BRONCHOSCOPE IN DISIMPACTION OF FOREIGN BODIES.

A and *B* show an annular edema above the foreign body, *F*. At *C* the edematous mucosa is being repressed by the lip of the tube-mouth, permitting insinuation of the hook, *H*, past one side of the foreign body, which is then withdrawn to a convenient place for application of the forceps. This repression by the lip is often used for purposes other than the insertion of hooks. The lip of the esophagoscope can be used in the same way.

done the bronchoscopy can be repeated any number of times. Therefore, it is absolutely unjustifiable to take the risk of pulling out an inorganic foreign body not free to move and from which the tissues cannot be protected in the position in which it is found. While it is undoubt-

edly true that if allowed to remain the foreign body will prove fatal, it will not prove fatal within weeks or, in many cases, even months.

FIG. 324.—THE SPECIMENS DEMONSTRATE THE INFINITE VARIETY OF THE MECHANICAL PROBLEMS INVOLVED IN EXTRACTION OF ENTANGLED IMPACTED FOREIGN BODIES OF VARIOUS FORMS AND COMPOSITION. ALL WERE REMOVED BLOODLESSLY THROUGH THE MOUTH WITHOUT ANÆSTHESIA. ILLUSTRATIONS ABOUT HALF SIZE.

Successful removal often depends upon the point of seizure and the proper version or rotation of the foreign body either before or after seizure.

Only too often in the early days of the work death promptly followed the ruthless tearing out of an entangled foreign body on the assumption

that it would prove fatal if allowed to remain. The motto should be, "Don't kill your patient; if you do, you cannot try again."

Mortality and Results of Bronchoscopic Foreign Body Extractions.—In the last 300 consecutive cases of foreign body in the air passages the intruder has been endoscopically removed bloodlessly through the mouth in 98 per cent. of the cases. There were only 3 deaths from any cause whatever within thirty days after the bronchoscopy, and this included cases which came in very serious condition. The mere passage of a bronchoscope is unassociated with any mortality if considered entirely apart from the condition for which it is

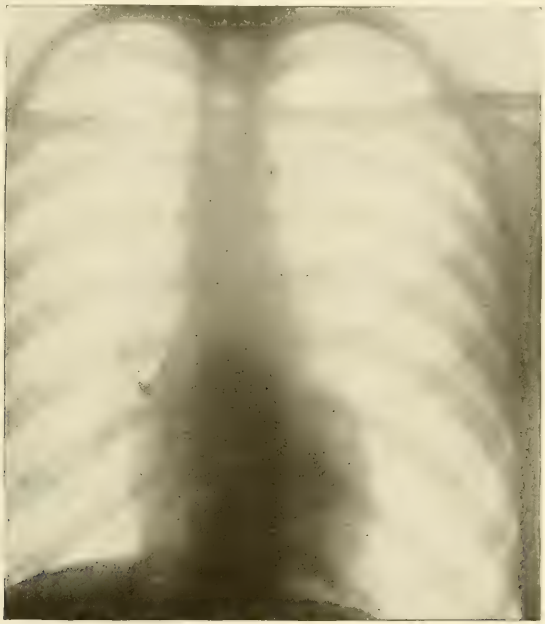

FIG. 325.—CASE NO. FBDY. 382. UPHOLSTERY TACK IN MIDDLE LOBE OF RIGHT BRONCHUS OF BOY AGED EIGHTEEN YEARS.

Sojourn about seven months. Note pathologic shadows over middle lobe area. These, as shown by a subsequent roentgenogram, have completely disappeared following bloodless peroral bronchoscopic removal of the tack.

done. Undoubtedly the mortality encountered in the early days of the work was due to deficient skill and failure to recognize the danger of prolonged bronchoscopy in children. The duration should not be over twenty minutes in a child under one year of age, thirty minutes under five years of age. Bronchoscopies of this duration can be repeated once a week if necessary for a year without any harm to the patient if no anesthetic be used, and, of course, if the utmost gentleness of manipulation be observed.* The structures are tender and vital and anything like heavy-handed manipulation may be fatal. Overdistention of a bronchus by the use of too large a tube, or the tearing of the

*Usually only a few minutes are required for bronchoscopic removal of a foreign body. For clinical data on recovery from pulmonary abscess after bronchoscopic removal of foreign bodies, see Mütter Lecture, Surg., Gyn., and Obst., March, 1919.

bronchial wall in disentangling a foreign body, may result in death within a few minutes from hemorrhage; in a few hours from mediastinal emphysema, or in a few days from septic mediastinitis.

Tracheotomic Bronchoscopy.—In the early days of the development of the work it was considered necessary in many cases to do a tracheotomy for the insertion of a bronchoscopic tube. Development of an improved technic and improved armamentarium have rendered the tracheotomic route obsolete. There is absolutely no advantage whatever in passing the bronchoscope through a wound in the neck as compared with passing it through the mouth. If anything, the peroral route is much more favorable. Of course, tracheotomy may be required for dyspnea, and, if so, should be done; but in such a case the subsequent bronchoscopy should be done through the mouth and not

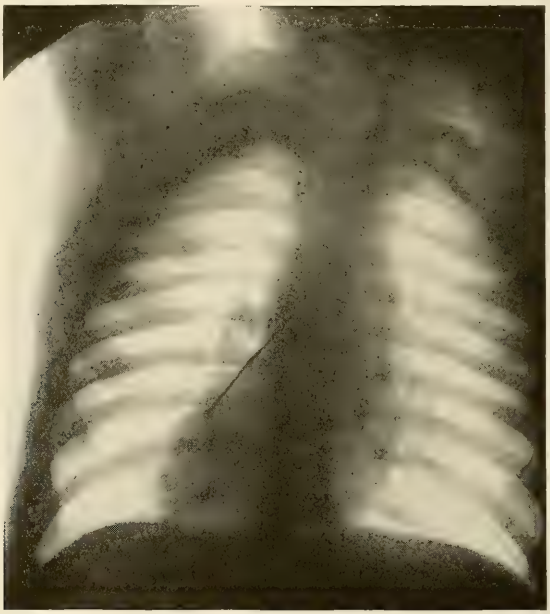

FIG. 326.—CASE NO. FBDY, 394. SHAWL PIN IN LEFT BRONCHUS OF AN INFANT AGED EIGHTEEN MONTHS. REMOVED BY PERORAL BRONCHOSCOPY WITHOUT ANESTHESIA, GENERAL OR LOCAL.

through the tracheotomy wound. Of the last 300 cases of foreign body in the bronchi in my own clinic the 294 foreign bodies that have been removed have been taken out through the mouth.

Fluoroscopic bronchoscopy is associated with a very much higher mortality than ocularly guided bronchoscopy, as the following statistics of fluoroscopic bronchoscopies for foreign bodies by various operators will show:

Foreign body removed in	8 (66.7 per cent.).
Foreign bodies not removed	4 (33.3 per cent.).
Number of cases fatal within a week	5 (41.6 per cent.).
Of fatal cases foreign body removed in	3 (50 per cent.).
Of fatal cases foreign body not removed in	2 (40 per cent.).

Of the successful cases, all but one could have been more quickly and safely removed by regular bronchoscopy, as they were instances of large foreign bodies in the main bronchi.

From the foregoing it is clear that fluoroscopic bronchoscopy, because of its high mortality and its low percentage of successes, has noth-

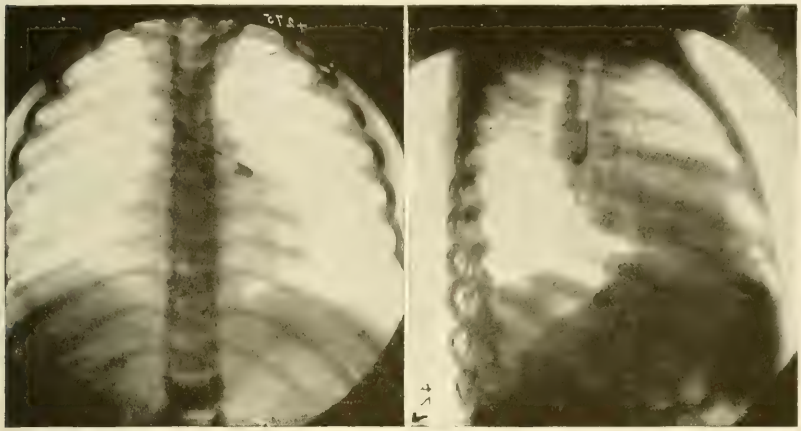

FIG. 327.—CASE NO. FBDY. 617. PORTION OF SAFETY-PIN IN LEFT BRONCHUS OF GIRL AGED THREE YEARS. REMOVED BLOODLESSLY THROUGH THE MOUTH IN TWO MINUTES, ELEVEN SECONDS, WITHOUT ANESTHESIA, GENERAL OR LOCAL.

ing to justify its use in any bronchially lodged foreign-body case until after regular, ocularly guided, endoscopic bronchoscopy has failed. The only cases in which its use is justifiable are those in which a small

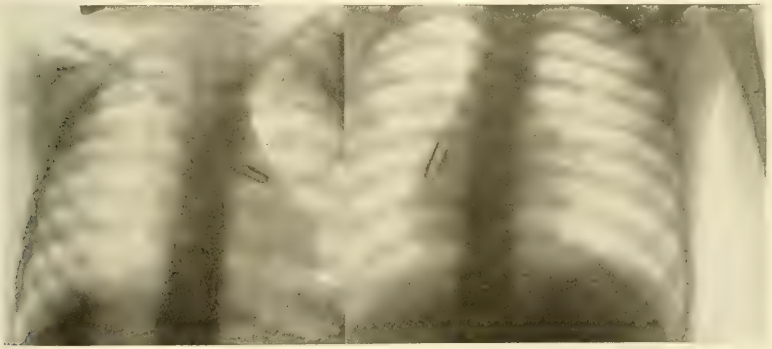

FIG. 328.—CASE NO. FBDY. 634. STAPLE IN THE LEFT MAIN BRONCHUS OF A FOUR-YEAR-OLD BOY. The left-hand radiograph shows the staple in the position it occupied before the bronchoscopy done prior to admission. When admitted the staple was found to be in the position shown in the right-hand radiograph, being deeper but still in the same lung, the left. The apparent reversal is due to the fact that one radiograph was taken with the plate at the front of the chest and the other with the plate at the back. Bronchoscopic "version" was done and the staple removed through the mouth without anesthesia, general or local, and without injury to the patient. Patient made a complete recovery.

foreign body has gone far out to the periphery because of its small size, or in those in which a large foreign body has worked its way out to the periphery by pathologic processes. In such cases the bronchoscopist should work by sight through the tube while the fluoroscopist tells

him whether he should search farther to the right or farther to the left, anteriorly, or posteriorly, as the case may be.

Peroral Bronchoscopic Removal of Foreign Bodies that Have Entered the Lungs Through the Chest Wall.—Projectiles and other foreign bodies that have entered the lungs through the chest wall doubtless can be removed in some instances with the bronchoscope. Such cases, however, have not yet presented themselves for bronchoscopy, so far as I am aware. The ease with which foreign bodies that have entered the tissues from the bronchi have been removed by bronchoscopy in many cases, and an almost total freedom of the method from mortality, would seem to render the trial advisable before proceeding to the opening of the chest. The field of possibilities is limited only by the size of the main bronchus. Obviously, a foreign body whose two least diameters is greater than the lumen of the main bronchus cannot safely be withdrawn through the natural passages. The length would be immaterial, because the foreign body could be turned so that its long axis would correspond to the axis of the bronchi and trachea during withdrawal, as is frequently necessary in dealing with foreign bodies that have entered through the natural passages.

ESOPHAGOSCOPY

Introduction of the Esophagoscope.—The patient should be in the position already described (Fig. 313). It may be well here to emphasize again the fact that the patient's head must be high during the first stage of introduction.

For safety the esophagoscope must be passed by sight. The essentials of my own method are as follows:

1. The correct "high-low" position-sequence of the patient.
2. A knowledge of the endoscopic anatomy in the living.
3. A clear conception of the direction and changes of direction of the esophageal axis as herein given.
4. A good general sense of direction that enables the endoscopist to point his esophagoscope in the general direction of the axis of the esophagus.
5. A clear mental image of the esophagus and its direction in relation to the esophagoscope.

With these qualifications the endoscopist has only to follow the landmarks to be able quickly to pass the esophagoscope on any human being whose mouth can be opened. The introduction may be divided into four stages:

1. Entering the right pyriform sinus.
2. Passing the cricopharyngeus.
3. Passing through the thoracic esophagus.
4. Passing the hiatus.

First stage: Entering the pyriform sinus is readily understood by looking at the schema (Fig. 329). The aspirating tube being attached and the esophagoscope properly illuminated, the collar of the esophagoscope is held lightly between the thumb and fingers of the right hand,

while the left hand rests on the patient's upper jaw, the second and third fingers being inside of the alveolus, the thumb and index-fingers supporting the tube, in much the same way as a billiard cue is handled. In order that the proximal end of the tube mouth shall be kept very high the operator is standing erect with his eye at the proximal tube

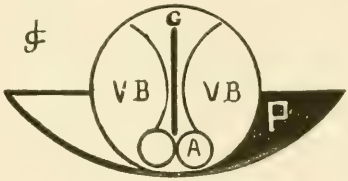

FIG. 329.—SCHEMA FOR FINDING THE PYRIFORM SINUS IN THE AUTHOR'S METHOD OF ESOPHAGOSCOPY.

The large circle represents the cricoid cartilage. *G*, Glottic chink, spasmodically closed. *VB*, Ventricular band. *A*, Right arytenoid eminence. *P*, Right pyriform sinus, through which the tube is passed in the recumbent posture. The pyriform sinuses are the normal food passages.

mouth while he seeks the right pyriform sinus. The landmark is the right arytenoid eminence. Great care must be taken to identify this arytenoid eminence. Great care must also be taken to avoid hooking the tube mouth over this eminence, which accident would

FIG. 330.—ESOPHAGOSCOPY BY THE AUTHOR'S HIGH-LOW METHOD. FIRST STAGE. FINDING THE RIGHT PYRIFORM SINUS.

In this and the second stage the patient's vertex is about 15 cm. above the level of the table and in full extension.

result in the prevention of further insertion, and, if force be used, the arytenoid motility might be seriously impaired. Having found the right arytenoid, the tube glides in readily for 2 or 3 cm., when it comes to a full stop and the lumen disappears. This is the spasmodically closed cricopharyngeal constriction. During stage one or

any of the stages the fingers are not inserted in the mouth, except so far as necessary for the hooking of the phalanges over the alveolus in order to get anchorage for the tube (Fig. 330).

Second stage: Passing the cricopharyngeus is, with the beginner, the most difficult part of esophagoscopy, especially if the patient is not anesthetized. Local anesthesia does not help. The relaxation of deep anesthesia does help very greatly, but it does not seem justifiable to use an anesthetic for this purpose alone, when, by practice, the operator can acquire the knack of passing the esophagoscope quite as easily without an anesthetic as with it. When the solid firm resistance of the cricopharyngeal fold is felt, force must not be used; only a steady firm pressure should be made on the esophagoscope while a strongly anterior (lifting in the recumbent position) movement is imparted to the distal end of the esophagoscope by the thumb of the left hand, support of which is afforded by the second, third, and fourth fingers

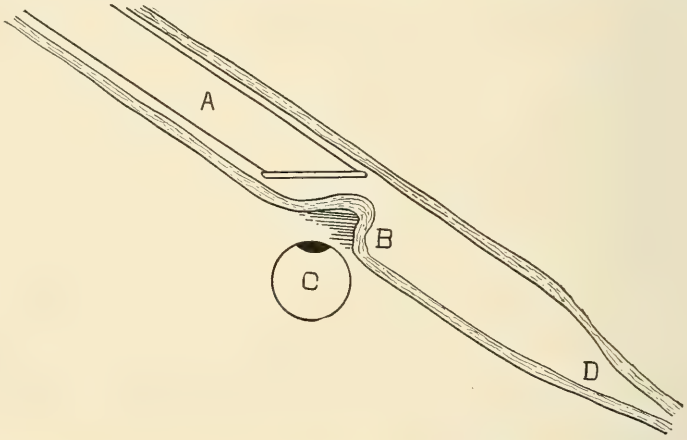

FIG. 331.—SCHEMA SHOWING HOW THE TUBE-MOUTH (*A*) IS LIFTED FORWARD TO RAISE IT OVER THE CRICOPHARYNGEAL FOLD (*B*) AS THE LATTER RELAXES, AND THE LUMEN OPENS UP AT THE TOP OF THE FIELD (*C*).

inside the alveolus. During this process it is necessary to keep the tube very high. There is a great temptation to lower the proximal end and it requires firm determination on the part of the esophagoscopist to resist this tendency. At the same time the lifting motion is imparted with the thumb, the distal end of the esophagoscope should be guided slightly toward the middle line of the body as the esophagoscope is *lifted over* (patient recumbent) the fold on the posterior pharyngo-esophageal wall. Alternate pressing and releasing will not accomplish the result. As it is with depressing the rebellious tongue, the pressure should be continuous, not intermittent; firm, though not forcible. The lumen should be watched for anteriorly, and if it does not quickly appear, the patient should be told to take a deep breath. A little patience here will always succeed. It is very essential that the handle be upward toward the ceiling in order to be certain that the lip of the esophagoscope is anterior. The manner in which this favors riding up

over the obstruction of the cricopharyngeal fold will be understood by study of Fig. 331. Perforation is most apt to occur at the weak point in the esophageal wall between the oblique and orbicular fibers of the inferior constrictor. This is the same weakly supported point through which the esophageal wall herniates in the genesis of a diverticulum. After passing the cricopharyngeal fold it is noted that the cervical esophagus presents almost no resistance to the tube.

Third stage: The esophagoscope usually glides easily through the thoracic esophagus. If it does not, the patient's position is faulty or the esophagoscope is being fixed by friction on the upper teeth. The lumen of the esophagus must be followed very carefully and very accurately by watching it open up ahead, which it does as the result of negative pressure during inspiration. The levels of the aorta and left bronchus are readily recognized and after passing them the lumen of the esophagus seems to have more and more of a tendency to disappear anteriorly. This is the signal for lowering the head, which has until now been kept high (note the schematic illustration, Fig. 334).

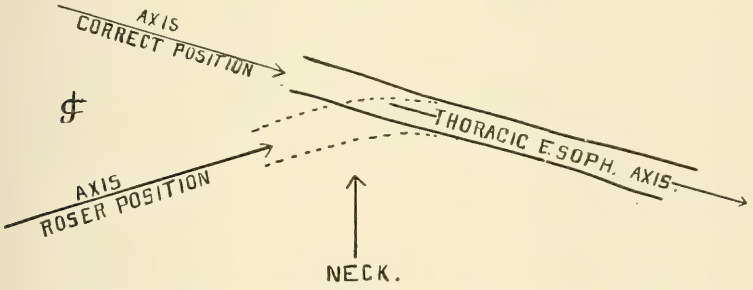

Fig. 332.—Schematic Illustration of the Author's "High-low" Method of Esophagoscopy. In the first and second stages the patient's head fully extended is held so as to bring it in line with the thoracic esophagus, as shown above. The Rose position is shown by way of accentuation.

Fourth stage: Passing the hiatus is very easy after a little practice if the directions here given are followed. The direction of the lower esophagus is anteriorly and to the left. To follow this direction during esophagoscopy upon the recumbent patient the head is dropped as shown in Figs. 333, 334. When the head is dropped it must at the same time be moved horizontally to the right in order that the axis of the esophagoscope shall correspond to the axis of the lower third of the esophagus, which deviates to the left, so that the tube is pointing in the general direction of the anterior spine of the left ileum. This brings the tube mouth quickly to the hiatal constriction, which is a spasmodically closed, rosette- or slit-like orifice due to the contraction of the musculature of the diaphragm surrounding the esophagus at the hiatus esophageus. If the esophagus is normal the slit is very readily found, and gentle but firm and continuous pressure is made until the spasmodic contraction yields and the esophagoscope glides quickly through the abdominal esophagus, the length of which is approximately from 2 to 4 cm. in the adult. So quickly is this abdominal esophagus

passed that early esophagoscopists mistook the hiatal opening for the cardia. I finally demonstrated the error. My high-low method of

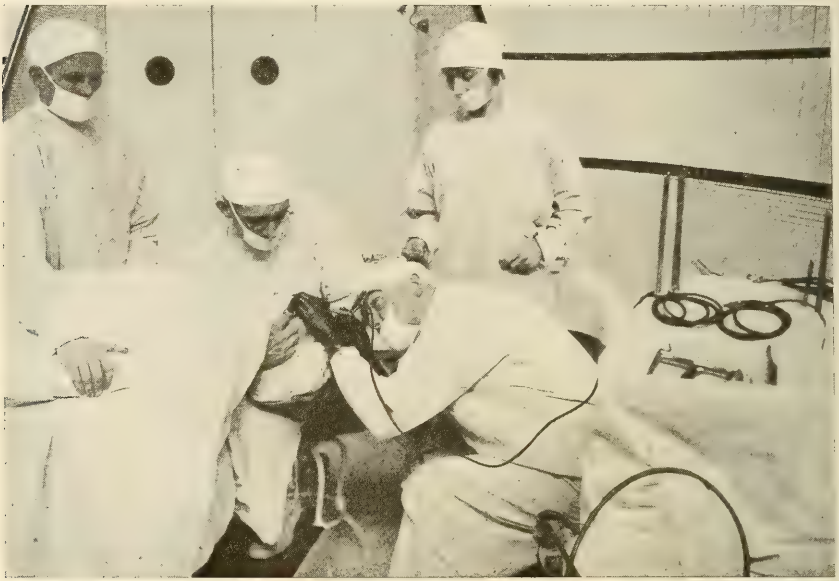

FIG. 333.—ESOPHAGOSCOPY BY THE AUTHOR'S "HIGH-LOW" METHOD. STAGE FOUR. PASSING THE HIATUS.

The patient's vertex is about 5 cm. below the top of the table.

esophagoscopy can be more readily understood by Figs. 330–333. It is in the perfecting of this method that esophagoscopy has developed

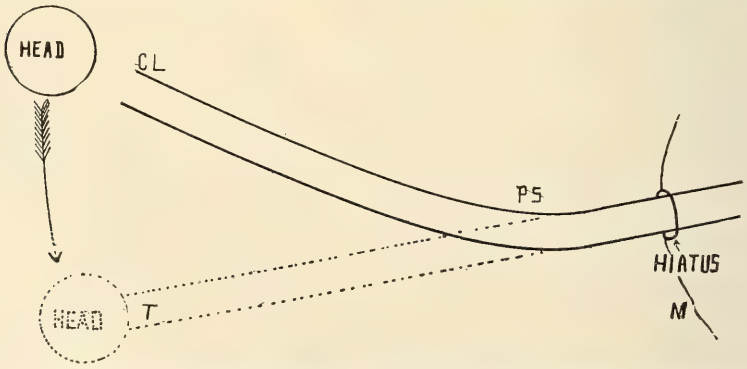

FIG. 334.—SCHEMATIC ILLUSTRATION OF THE AUTHOR'S "HIGH-LOW" METHOD OF ESOPHAGOSCOPY. FOURTH STAGE. PASSING THE HIATUS.

The head is dropped from the position of the first and second stages, *CL*, to the position *T*, and at the same time the head and shoulders are moved to the right (without rotation) which gives the necessary direction for passing the hiatus.

from a slow, laborious, uncertain, often dangerous and impossible procedure into a very smooth satisfactory technic by which the esophagoscope can be passed in a few seconds in any patient that can open his

mouth, provided the esophagus is not occluded by a lesion. The perfection of the method depends upon practice and upon the position of the patient which was developed by Dr. Boyce in conjunction with myself. No other position yields the same freedom of movement, a freedom that permits the patient to be promptly moved about in every direction in order that the operator may follow the lumen. Various mechanical methods of anchoring and fixing the patients have been advocated, but all of them are a hindrance rather than a help so far as the introduction of the esophagoscope is concerned. Practice upon the cadaver under the tutelage of a skilful instructor is really necessary to learn the technic and the landmarks, and especially to learn how to avoid the mortality which is almost certain to follow uninstructed efforts at first upon the living. During esophagoscopy the aspirator which connects with the drainage-tube in the wall of the esophagoscope keeps the field free from secretions which are constantly coming up from the stomach no matter how long the patient has been kept without food or water. These secretions, being much more watery than those of the bronchi, are readily aspirated.

Esophagoscopy for Foreign Bodies.—When the esophagoscope reveals the foreign body the tube is stopped at once and fixed against the upper teeth by means of the finger anchorage. This retains the esophagoscope in relation to the foreign body. The anchorage being accomplished with the left hand, the right is free to take the forceps, which is applied in the direction which has been determined by the previous observation of the foreign body itself. In the case of a foreign body such as a coin or button the intruder is seized flatwise and withdrawn, care being taken to keep its plane in correspondence with the lateral plane of the patient's body. When, as is usually the case, the foreign body is too large to come through the esophagoscope, the intruder is held closely against the tip of the tube mouth while forceps, foreign body, and esophagoscope are all withdrawn together. If the foreign body has sharp points it must under no circumstances be pulled upon until the relation of these points to the mucosa is determined and the foreign body allowed to rotate into such a position that the esophageal wall will not be wounded. Traumatic esophagitis is almost invariably fatal.

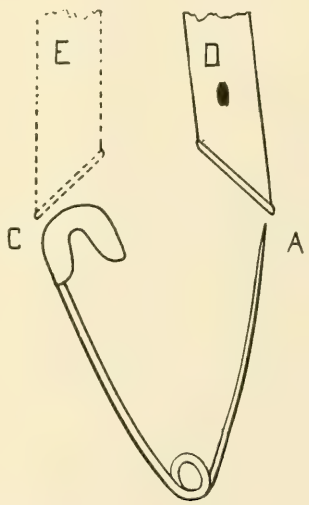

Fig. 335.—The Problem of the Safety-pin.
Forty-eight safety-pins have been endoscopically removed from the larynx, trachea, bronchi, and esophagus, in the author's clinic, by this and other peroral endoscopic methods.

Safety-pins may be closed by the method illustrated in Fig. 321,

or they may be carefully passed down into the stomach, turned, and removed. Still another method is shown in Fig. 335. The execution of any of these requires a great deal of preliminary practice with an esophagoscope inserted in a piece of rubber tubing in which a safety-

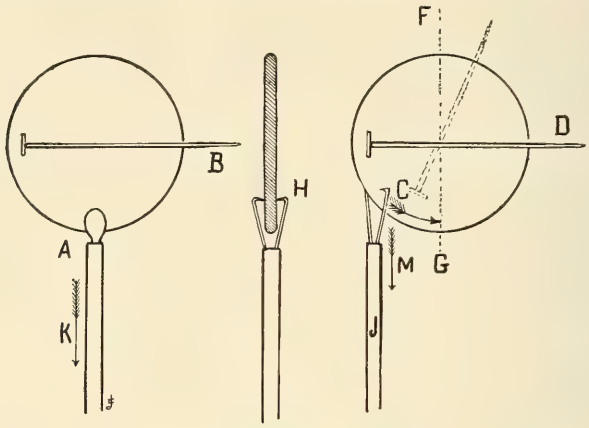

FIG. 336.—SOLUTION OF THE MECHANICAL PROBLEM OF THE BUTTON OR OTHER DISK-LIKE OBJECT WITH A SHARP POINT.

If withdrawn with a plain forceps applied as at *A*, the point, *B*, will rip open the esophageal wall. If grasped at *C*, the point, *D*, will rotate in the direction of *F* and will trail harmlessly behind. To permit rotation the author's rotation forceps are used as at *H*.

pin has been fixed in a position to simulate as nearly as possible a lodgment in the esophagus.

Buttons which have a sharp point are removed quickly and safely by the method illustrated in Fig. 336. Meat and other soft substances may be removed readily with a mechanical spoon (Fig. 337). My own

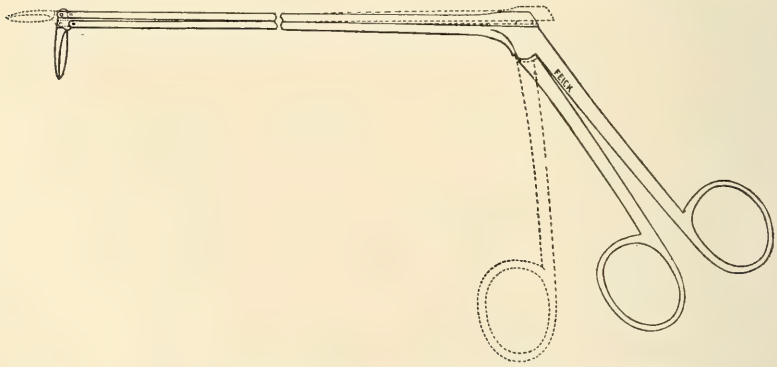

FIG. 337.—MECHANICAL SPOON (ALLIGATOR) FOR SHORT ESOPHAGOSCOPE.
A longer model is made for the esophagoscope.

forceps are very convenient for reaching below the cricopharyngeus into the region in which foreign bodies most often lodge in the esophagus.

Esophagoscopy for Disease.—Cicatricial stricture of the esophagus is very safely treated by means of the filiform bougies (Fig. 338) passed

through the esophagoscope by sight. The usual method is to dilate the esophagus with increasing sizes at intervals of about one week, no anesthetic, general or local, being used. When the bougie enters it is gripped by the walls of the stricture which resist its further progress. On removing the bougie, the esophagoscope should be first withdrawn for a few centimeters so that the cone of esophageal mucosa, produced by the retraction of the bougie gripped by the walls of the stricture, be not bruised by drawing it into the esophagoscope. The method is vastly safer than any form of divulsion or of pulling through various dilators with threads. All procedures being under the guidance of the eye, no stretching is done in the case of ulceration, which is a very frequent attendant owing to stagnation of food in the esophagus above the stricture. Such cases are treated by the local application of silver nitrate or argyrol and the internal administration of bismuth subnitrate dry on the tongue. As soon as the ulceration has healed the dilatation is proceeded with, the result being a cure in all cases in which there is not a total permanent cicatricial atresia.

Esophagoscopy for Hiatal Esophagismus (So-called "Cardiospasm").—This condition is very readily recognized by the enormous dilatation of the esophagus, usually filled with stale food. The mucosa is coated

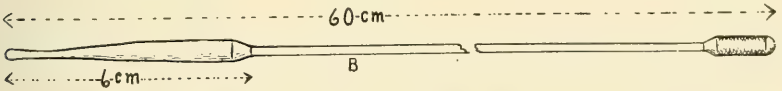

Fig. 338.—Filiform Bougie for Minute Cicatricial Strictures of the Esophagus.

The filiform silk woven end, *A*, is joined securely to a spring steel shaft, *B*, thus giving all the advantages in safety of a silk woven bougie at the tip with a stiff shank that enables the bougie to be carried down rigidly through the length of the esophagoscope. Twelve sizes are made. The total length of 60 cm. is only necessary in case of a very low stricture in an adult. For use in children, the bougie can be shortened by unscrewing. The great advantage of the steel shaft over any sort of stylet inserted into a hollow filiform is that the small diameter of the steel shank permits of more accurate ocular guidance.

with a white, pasty, adherent material which is in strong contrast with the pale shining pink mucosa of the normal esophagus. When the level of the hiatus is reached a broad floor is found to exist in the dilatation, and in this floor the hiatus must be searched for. It will be tightly, spasmodically closed when found, but gentle pressure continued without intermission will cause it to yield and the esophagoscope will readily glide into the stomach. Esophagoscopy with a large sized esophagoscope is itself a very efficient form of treatment. If it fail, a mechanical dilator can be very readily used through the esophagoscope with excellent results, and with perfect safety to the patient.

Esophagoscopy in Malignant Disease of the Esophagus.—Esophagoscopy affords the only means of making a very early diagnosis of esophageal cancer. If every patient who has the slightest symptom referable to the swallowing function were esophagoscoped, esophageal cancer could be discovered very early and the diagnosis could be absolutely determined by the taking of a specimen with the forceps shown at *E*, Fig. 308. The rapid development of thoracic surgery renders it hopeful that this early diagnosis will enable the patient to obtain a

cure by external operation. No endo-esophageal operation seems justifiable. Radium can be applied through the esophagoscope, and has been quite efficient in retarding the progress of lesions not too far ad-

FIG. 339.—FOREIGN BODIES (HALF SIZE) REMOVED FROM THE ESOPHAGUS BLOODLESSLY BY ESOPHAGOSCOPY THROUGH THE MOUTH, WITHOUT ANESTHESIA, GENERAL OR LOCAL.
(From author's collection of over 800 specimens.)

vanced. Large lesions are probably irritated. The malignantly stenosed lumen can be intubated for palliation by the esophagoscopic placement of silk-woven Charters-Symonds or Guisez tube.

GASTROSCOPY

The stomach is easily entered with the esophagoscope by the technic given under Introduction of the Esophagoscope. A large latitude of movement is permitted by the dome shape of the diaphragm which amounts to redundancy. The stomach, when the gastroscope enters it, has no definite shape. It is a mass of collapsed folds which are manipulated apart by the tube mouth. No matter how long the fast may have been, thin watery fluid flows from every crevice. This is quickly carried away by the aspirating canal in the wall of the esophagoscope or gastroscope. The stomach is searched systematically by lateral and vertical traverse as with the mechanical stage of a microscope.

Gastroscopy for diagnosis is especially useful for the determination of suspected surgical conditions in patients who refuse exploratory operation. Malignant disease can be diagnosticated by clinical appearance and by taking a specimen of tissue for biopsy. Positive findings are invaluable; negative results are of little value, because the pyloric extremity amounting to as much as one-third of the stomach is unexplorable in many cases.

Gastroscopy for foreign bodies is a practical procedure available for the removal of any foreign body that, because of its size or shape, will not pass the pylorus. As a rule, any foreign body that has reached the stomach spontaneously will in time pass the normal pylorus. In case of foreign bodies pushed into the stomach, or of pyloric stenosis, gastroscopy is clearly indicated.

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CHAPTER XLI

SURGERY OF THE THORAX*

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Baltimore, Md.

During the period which has elapsed since the publication of Volume VI of this work surgeons of all countries to which we look for surgical contributions have largely devoted themselves to the study of war injuries; and perhaps in no field with greater profit than in the special domain of thoracic surgery. The stimulus to the study of chest wounds was indeed great. The expectant treatment of all these injuries, almost invariably adopted as the result of experience gained in previous wars, was found totally inadequate in certain types of them, and was followed by an unexpectedly high mortality. Fearing surgical pneumothorax and lacking special differential pressure apparatus, surgeons at first hesitated to attack the thorax, but later felt compelled to do so in the hope of obtaining better results. To the surprise of many it was found that the thorax might be opened with comparative safety and that the pleura and lung tolerated well the surgical procedures necessary in the treatment of war wounds. The field then became one of the most fascinating to physicians and surgeons alike, and was studied as intensively as the exigencies of war permitted. As a result of this study and the experience gained in the treatment of thousands of cases much of value has been learned. We appreciate better the problems in the surgery of the thorax which require elucidation; we know more thoroughly the pathology of penetrating and non-penetrating chest wounds and of their immediate and late complications; we have a clearer idea of the pathologic physiology of "closed" and "open" thorax; we have placed a better evaluation upon the symptoms and physical signs which accompany these injuries and their complications; we have improved our *x*-ray diagnoses, especially from the standpoint of localization; we have been able more surely to group cases into those which may safely be treated expectantly and those which require active surgical therapy; we have learned better surgical approaches to the thoracic cavity and have had an opportunity to study the results of the various methods of excision and suture of the lung; and we have acquired some information on the late results of thoracic injuries. The

* Dr. George P. Pratt, of Omaha, Nebraska, and Dr. V. R. Mason, of Baltimore, were associated with me in the study of the 160 penetrating chest wounds which form the basis of my remarks upon this subject; to them and to Dr. Ira M. Lockwood, roentgenologist, of Lincoln, Nebraska, I take this opportunity of expressing my indebtedness.

Supplementary to Chapter XLI, Vol. III, p. 512, and Chapter CXVI, Vol. VI, p. 373.

greater part of this chapter will be required to discuss these various aspects of wounds of the thorax; but such application of the information gained in their treatment as may be made to civil surgery will be evident to the reader without special emphasis. Such new data in the surgery of civil life as have been acquired since the publication of Volume VI will be added to the subjects considered by Dr. Brewer in Volumes III and VI. The surgery of the heart, pericardium and great vessels, of the esophagus, trachea, and bronchi will be considered in other chapters.

Certain pathologic conditions—one or several of which are common to injuries of the thorax—will be considered before the conditions with which they are associated are described, an arrangement disconnected, perhaps, but necessary in order to avoid repetition.

HEMOTHORAX

Occurrence.—The condition as seen in association with closed wounds of the chest only is considered under this heading. Hemorrhage into the pleural cavity may occur as a result of *shell explosions* without sign of external wound; from *contusions* of the thorax due to crushing or compression injuries and blows by large objects; from *non-penetrating wounds* by bullet or shell fragment; from *penetrating wounds* of the chest by rifle bullet, shell fragment, or knife thrusts; or from *low thoracic injuries* associated with rupture or perforation of the diaphragm and injury to the liver and spleen.

Source of Bleeding.—In *shell explosions* hemorrhage has been found at autopsy to be due to rupture of the lung. In *contusions* it may occur from subcutaneous laceration of the intercostal vessels, from rupture of the lung, or laceration of this organ by rib fragments; and from areas of hemorrhagic infiltration or infarction in the lung, apparently by diapedesis through an intact pleura. In *penetrating wounds*, it is derived from the intercostal vessels, the internal mammary artery or vein, the azygos veins, the great vessels about the hilum of the lung or the heart, the vessels in the wounded lung, and from the injured liver or spleen in association with wounds of the diaphragm. In those who survive to reach the forward hospitals it may be impossible in many instances to determine the source of the bleeding. The great majority of authors agree that hemothorax is derived in most instances from the bleeding lung, and the few careful pathologic examinations available as well as the surgical experiences of many confirm this opinion. In our own experience, in operations conducted through the wound, we have never seen a bleeding intercostal vessel and but once a bleeding internal mammary artery.

Incidence.—In *contusions* of the thorax we have no accurate data regarding the frequency of hemothorax. In the milder grades of injury it is uncommon; in the severer types it may be expected. In my own series of severe contusions by aëroplane crashes, crushing injuries, blows from swiftly moving large objects, and non-penetrating shell wounds it has been present in almost all instances. In *penetrating wounds* we

have more accurate data; and from a survey of reports from many authors, which our own series of 160 cases confirms, it occurs in from 70 to 90 per cent. of the cases. The great variation in frequency seen in different series of statistics is probably due to the methods of examination. Those authors who have arrived at their diagnoses with the aid of exploratory puncture invariably show a high percentage of hemothorax; those who have based them on physical examination alone have, in all probability, missed the smaller collections of fluid.

Amount and Location of Hemorrhage.—The amount of bleeding into the thoracic cavity varies greatly. In *contusion* it is usually slight (from 50 to 500 c.c.). It may, however, in the severer types of contusion be large, as in one case of our own in which on successive days 1000 and 800 c.c. of blood were removed because of pressure symptoms. In *penetrating wounds* the amount of blood may vary from a small amount collected in the costodiaphragmatic sulcus to 1 to 3 liters. The largest amount of fluid found at autopsy by Henry and Elliott[52] in cases of sterile hemothorax was 2250 c.c. In unilateral injuries the hemorrhage takes place on the wounded side alone in the larger proportion of cases; but in the injuries associated with great contusions, bleeding, although small in amount, may occur also on the contralateral side. Attention has been called to this contralateral bleeding by physical signs and has been proved by aspiration and at autopsy. The mechanism of its production is explained either by rupture of the opposite lung by contrecoup, or by seepage through an apparently intact visceral pleura from an area of hemorrhagic infiltration in the contralateral lung. In the oblique injuries penetration of the chest with hemothorax may occur on the side opposite to the wound of entrance. In the transverse penetrating or perforating wounds hemorrhage may take place into both pleural cavities, giving rise to a bilateral hemothorax.

The blood derived either from the parietal wall or lung gravitates into the costodiaphragmatic sulcus and, depending upon the severity of the hemorrhage, gradually fills the thoracic cavity, reaching to the level of the scapula or even to the clavicle (Fig. 340). With the filling of the chest certain changes occur with respect to the lung, the diaphragm, and the mediastinum. The lung undergoes collapse, which at first is partial, but may continue until the lung has shrunk to a small volume at the hilum. During the course of this collapse the lung is at first lifted up by the accumulating blood and floats upon it. The lower lobe or the lower and middle lobes become compressed against the vertebral groove, the root of the lung, or the pericardium. The upper lobe is at first overdistended and emphysematous; later it also becomes collapsed and atelectatic. Undoubtedly this collapse of the lung tends to check the bleeding from the wounded parenchyma, and the splinting of the collapsed lung by the hemothorax acts as a further check. The diaphragm, especially in the early period of the injury, has been observed both by physical signs and by fluoroscopic and *x*-ray examination to occupy a high position, and often by fluoroscopic examination is seen to be immobile. It occupies, therefore, the cadaveric position such as

is assumed in complete relaxation of the muscle. This unexpected finding has been noted by many British, French, and German authors, and has been observed in our own series of cases. By some it has been seen in all types of intrathoracic conditions associated with chest injuries, by others is considered to be peculiarly associated with hemothorax. The explanation of the condition is not at all clear, and the theories for its causation thus far advanced seem to us unsatisfactory. A few authors, on the other hand, have noted a flattened diaphragm in massive hemothorax. The mediastinum is commonly displaced toward the

FIG. 340.—HEMOTHORAX COMPLETELY FILLING THE RIGHT THORACIC CAVITY. LARGE RETAINED FOREIGN BODY. MEDIASTINUM DISPLACED TO THE LEFT. (Author's series.)

sound side. This is invariably observed in the large hemorrhages, but also occurs in those the size of which does not seem to warrant mediastinal displacement. In massive hemothorax it may be so great as to give rise to active compression symptoms, such as cyanosis, dyspnea, and tachycardia.

The blood in hemothorax is, in most instances, fluid, and, while on aspiration resembling normal blood in all respects, does not clot on standing. The statement is not meant to imply that no clotting takes place in the closed thorax, for undoubtedly some clotted blood is found about the wound in the lung or parietal wall together with a fibrin clot

in the costodiaphragmatic sulcus. There may, moreover, be more extensive clotting than this. The hemothorax may be made up about equally of clotted and fluid blood—as we have observed—or may rarely take the form of a massive clot, described particularly by British authors, which defeats all attempts at aspiration. The failure of the blood to clot within the thorax or on standing after aspiration is explained by the majority of authors as due to the separation of the fibrin from the blood which is more or less agitated by the cardiac and respiratory movements. Dorlencourt and Paychères[25] do not agree with this more or less simple explanation, but find that hemothorax fluid is not only non-coagulable but anticoagulant, due to a peculiar substance, possibly of the nature of a histone, which is added in the chest.

Evolution and Cytology of Hemothorax.—In closed hemothorax the maximum hemorrhage takes place within the first twenty-four hours after the injury. It rarely continues for forty-eight hours. Bleeding, therefore, is fairly rapid, but tends to cease spontaneously because of the collapse of the lung and the splinting of the lung by the accumulated fluid; yet it is found that the fluid in the chest may rapidly reaccumulate after an aspiration done, for example, for pressure symptoms. This reaccumulation of fluid is not due to a continued or to a new hemorrhage, but to the outpouring of a pleural effusion, the result of an aseptic pleural inflammatory reaction. In the late stages of hemothorax the fluid may be largely serous.

The cytology of sterile hemothorax fluid has been quite extensively studied, and in general the findings of different observers are in agreement. In the early stages the aseptic fluid shows a cell count essentially similar to that of normal blood, but with fewer red cells. There follows a gradually rising polymorphonuclear leukocytosis, which is interpreted by some as a defensive reaction against infection. In the subsequent course there is a drop in the number of leukocytes, persisting for a variable time and due to the dilution of the blood by the pleural effusion. This stage is followed by a secondary rise in leukocytes, but of the eosinophilic and mononuclear leukocytic variety, and is associated with restoration and reparation. An increase in the endothelial cells or phagocytic cells is common.

Course and Sequelæ of Hemothorax.—In the uncomplicated sterile closed hemothorax the tendency is toward spontaneous absorption. The rapidity of absorption is dependent upon the size of the hemothorax. Small collections of blood may be completely absorbed in a period of weeks; large collections may not be absorbed for months. The results of this slow process of absorption have been frequently commented upon and include retraction and flattening of the chest, thickening of the pleura, obliteration of the costodiaphragmatic sulcus, and fixation of the diaphragm. They cause marked diminution in the functional capacity of the lung on the affected side, and often give rise to subjective symptoms, such as pain, dyspnea, and tachycardia on exertion.

Late Hemorrhage in Closed Hemothorax.—As has been previously noted, hemorrhage resulting in hemothorax takes place within the

first twenty-four to forty-eight hours after the injury. Practically all authors agree that after the third day there is no danger from bleeding, and an examination of the literature covering thousands of cases shows that secondary hemorrhage into the thorax is very rare. In a series of 110 cases with closed hemothorax we have seen two instances: one a fatal hemorrhage from a torn internal mammary artery occurring on the sixth day after the injury; the second on the tenth day, following an effort to sit up in bed. Infection undoubtedly was responsible for the late hemorrhage in the latter.

Complications in Hemothorax.—The only complication requiring consideration is infection. Statistics gathered from earlier wars in which the small, high velocity, jacketed bullet was used, and from penetrating wounds in civil life, showed that infection occurred but rarely in association with hemothorax. Makins,[73] in the South African War, during the whole campaign saw only a single case of primary empyema, and but few instances of secondary empyema. In the Russo-Japanese War the incidence of infection in closed wounds was low. In the recent war conditions were quite changed. Due to the trench type of warfare, the highly infected terrain, and the character of the missiles the incidence of infection was very high and was the real cause of the mortality among those who did not die within the first forty-eight hours from hemorrhage, shock, and extensive wounds. The literature shows a great variation in the incidence of infection in hemothorax, and one cannot take as a criterion the experience of a single author whose activities have been limited to a certain hospital. The true incidence of infection is more nearly, though perhaps also incorrectly, represented by the sum of infection in hospitals at the front, along the lines of communication, and at the base. Judged in this way infection of hemothorax occurred in association with closed chest wounds in from 15 to 30 per cent. of all cases, and was responsible for from 50 to 80 per cent. of the mortality.

The source of infection may be either from without, carried in by the foreign body; or from within, from the wound in the lung. The species of infecting organisms give us some idea of the frequency of the two types of infection. The available statistics show that in infected hemothorax the influenza bacillus, the pneumococcus, and the Micrococcus tetragenus—in other words, pulmonary organisms—occur in about 20 per cent. of the cases; the streptococcus and staphylococcus together in about 40 per cent.; various anaërobic bacilli in 23 per cent., or in association with other organisms in an additional 19 per cent., and other organisms in about 5 per cent. In most instances the infections are multiple. In 80 per cent. of the cases, therefore, infection was carried into the pleura from without.*

The changes in the fluid vary with the type of the infecting organism, the duration and severity of the infection before aspiration is per-

* The statement is open to question, for streptococci, which were commonly found in infected hemothorax, were often inhabitants of the respiratory tract; and therefore might also be considered as pulmonary organisms.

formed, and the time in the evolution of the hemothorax at which infection occurs. In the early stages of infected hemothorax the aspirated fluid may appear unchanged, but show an increase in polymorphonuclear leukocytes. With the further outpouring of these cells a pinkish fluid is obtained, the purulent nature of which is evident. If the infection occurs late, when the hemothorax is largely serous, a turbid yellow or frankly purulent fluid may be obtained. In infections due to anaërobic bacilli the aspirated blood often has a dark reddish-purple color and an extremely offensive odor.

The onset of infection in relation to the receipt of the injury may be early or late. The simple sterile hemothorax is associated with fever, which is fairly continuous, which reaches 100° to 103° F., which may persist for weeks, but which tends to fall in the course of the first week. The patient, after recovery from his primary shock, dyspnea, and tachycardia, feels well and looks well. In the instances of early infection the temperature does not return to normal, but may daily show a little elevation or assume a septic curve. The patient does not recover from his symptoms, as in sterile hemothorax, but instead complains of pain in his chest, is restless, has disturbed sleep, complains of dyspnea, and has tachycardia. The physical signs of fluid may remain as before. In such cases infection should be suspected and aspiration performed for cultural purposes. In the second group of cases the infection begins late—from the fifth or sixth day to well into the third week. The patient, having recovered from his primary symptoms and being apparently on the road to recovery, develops an increased elevation of temperature or a secondary rise and complains of the symptoms above noted. On physical examination there may be an increase in the level of the effusion. Most striking and alarming are the infections caused by anaërobic organisms. The patient, while apparently doing well, may within twenty-four hours become very ill with a temperature of 104° F., a pulse of 120 to 140, and with dyspnea, cyanosis, toxemia, and delirium. There is a marked change in the physical findings due to formation of gas. The resulting pneumohemothorax is indicated by marked displacement of the heart and mediastinum and by an area of tympany above the fluid level. Fluoroscopic examination with the patient in the erect position shows a horizontal fluid line (Fig. 341). The explanations of these late infections are that the infecting organisms at first are included in the clotted blood and fibrin, and only later infect the general hemothorax by the breaking down of the clot; or that the infectious material carried into the lung at first sets up a local infection in the pulmonary parenchyma, which later spreads along the wound tract into the thorax. We have seen undoubted examples of both methods of late infection at autopsy. In the late infections by anaërobic bacilli the organisms may develop either slowly in the pleural cavity or within a massive clot, the rupture of which by the accumulated gas disseminates the organisms throughout the fluid.

It should be remembered that in contradistinction to the above remarks infection of hemothorax may be present with but few symp-

toms. In some of the milder infections there may be little or no elevation of temperature, no increase in the pulse-rate, no striking symptoms or physical signs; the patient simply does not feel well and his convalescence is prolonged. Even in gas-bacillus infection a low pulse-rate may be present, but it is almost invariably associated with high fever. The influence of pleural adhesions on the incidence of infection has been commented upon by various authors and has been noted in our own series. The failure of the lung to collapse tends to prevent the obliteration of the wound and thereby promotes the development of infection either by pulmonary organisms or organisms from without.

Fig. 341.—Pneumohemothorax from Perforating Wound Showing Fluid Level. *x*-Ray taken with patient in erect position. (Author's series.)

Coincident or subsequent complications of infected hemothorax are purulent bronchitis, septic bronchopneumonia, pleurisy of the contralateral side, purulent pericarditis, and septicemia.

Symptoms and Physical Signs of Hemothorax.—When seen shortly after his injury, the patient complains of weakness and vertigo and a hot burning pain in the chest. He may have cough and hemoptysis and a varying grade of shock, from very slight to severe. His pulse varies from 100 to 160, his blood-pressure is low. He has dyspnea and sometimes cyanosis; is anxious, restless, and very often cold. These urgent symptoms disappear with remarkable rapidity with ab-

solute rest, heat, and morphin. The day following the injury the entire picture is changed. The patient lies comfortably in bed, is calm, may still have pain and bloody cough, but his pulse has dropped to perhaps 90, his blood-pressure approaches normal, his color is good, his respiration is comparatively easy. One has the impression that the shock of the preceding day was out of all proportion to the amount of blood lost. The return to the normal, however, is not always so rapid and uneventful. If hemorrhage is severe the symptoms may persist over several days and compression symptoms due to displacement of the heart and mediastinum may supervene. Urgent dyspnea, cyanosis, and tachycardia may make aspiration of the fluid imperative.

The signs of hemothorax depend upon various factors, and it should be remembered that many of them are not due to the hemothorax *per se*, but to concomitant conditions. Cough is common and in perhaps 75 per cent. of the cases hemoptysis is present. This, as a rule, is slight, rarely more than a teaspoonful, and usually persists up to the fifth or sixth day. Blood-stained sputum, however, may be present for two weeks or more. The primary hemoptysis is due to the injury of the lung; the blood-streaked sputum which continues for a longer period is said by some to be due to an associated septic bronchopneumonia. The location of the pain may be in the immediate vicinity of the wound, or it may be referred to regions quite removed from it. Abdominal pain and an associated abdominal rigidity have been observed not infrequently in association with low thoracic injuries. Fever is the rule, even in sterile hemothorax. At the time of admission the temperature may be subnormal, associated with shock. With recovery from the shock the temperature rises to 100° to 101° F. and may rise to 103° and 104° F. It may show a continuous elevation over several days, or there may be slight remissions. In our series of 80 cases of uncomplicated closed hemothorax the temperature began to decline most frequently on the third or fourth day, but showed a daily rise to 99° or 100° F. for from ten days to two weeks. A relatively high fever, however, may persist for two weeks or more without cultural evidence of infection and may not completely disappear for three or four weeks. In a small group of cases with small effusions the temperature may be normal or practically normal on admission and continue so throughout the course. By cultural examination of aspirated fluid it has been shown that this fever need not be associated with infection. It has been assumed by most authors to be due to the absorption of blood from the pleural cavity. Piéry,[85] however, does not agree with this explanation, and believes that in all cases there is an associated pneumonic process which is responsible for the fever.

The *physical signs* of hemothorax are those of fluid in the chest and depend on the amount of fluid present. In all except the very slight cases, in which there is but a minimum amount of blood in the costodiaphragmatic sulcus, there is on inspection a retraction of the chest and limited respiratory movements. In the larger effusions the apex-beat may be seen far to the side. On palpation there may be no change

in the very slight effusion. In the moderate grades—reaching up to the angle or middle of the scapula—or in the massive grades tactile vocal fremitus is absent over the effusion or over an area slightly less than the effusion. It may be increased above the level of the fluid. On percussion there is dulness or flatness over the accumulated blood, which in the massive forms of hemothorax may reach the clavicle. In the moderate grades the dulness is replaced by tympany or Skodaic resonance above the effusion, associated with emphysema of the overlying lung. On auscultation the breath sounds are suppressed and tubular, or absent over the dull area; but occasionally tubular breath sounds over the collapsed lung within the hemothorax may be so loud and clear as to suggest that the lung is near the chest wall. Vocal resonance over the fluid is lost, but there may be bronchophony and whispered pectoriloquy. Over the emphysematous area above the fluid the breath sounds are generally weak, but may be loud and harsh. The vocal resonance is increased. Adventitious sounds are rare and were heard in only 7 of Howard's[55] 56 cases.

The *x-ray* or *fluoroscopic* examination (Fig. 340) shows a shadow, in size depending on the amount of the effusion, which is densest at the base, and, in the absence of air in the chest, shades off gradually above with no definite line of demarcation into two zones. The diaphragm, as noted previously, occupies a high position and is relatively immobile; but it may be low and flattened in the large effusions.

Diagnosis and Differential Diagnosis.—The nature of the injury, the more or less characteristic symptoms, the signs of fluid in the chest, the *x*-ray picture, and, in doubtful cases, the exploratory aspiration of the thorax make the diagnosis easy. Pneumonia, presumably of traumatic origin, may be wrongly diagnosed because of the fever, blood-stained sputum, dyspnea, tubular breath sounds, and loss of movement of the affected side. The differential points lie in the cardiac displacement, the absence of râles, and in the *x*-ray picture. Pneumothorax may be wrongly diagnosed when the emphysematous upper lobe above the effusion causes a tympanitic percussion note and weak breath sounds. Here the *x*-ray picture with the patient erect, showing a fluid level, establishes the diagnosis. Other conditions need not at present be considered.

Treatment.—The following remarks apply only to simple hemothorax unassociated with extensive rib fractures, open chest wounds, or large retained foreign bodies. These conditions will be taken up under the treatment of penetrating chest wounds. Absolute rest in bed in the position most comfortable from the standpoint of pain and dyspnea, morphin—if necessary, in large and repeated doses—to induce quiet, and measures to combat shock are the important features in the immediate treatment of hemothorax. In the slight injuries with small effusions nothing more is necessary. The patient responds promptly to his immediate treatment and is comfortable on the following day. The small amount of blood is spontaneously absorbed within a couple of weeks and the patient completely recovers, but with perhaps a

slightly thickened pleura and adhesions in the costodiaphragmatic angle. In the cases of moderate or large hemothorax the question of aspiration or thoracotomy for the removal of the retained blood arises. The former is done for two purposes—for diagnosis and for treatment.

Aspiration for Diagnosis.—The experience in the past war showed that every case of hemothorax was potentially infected. The difficulty in making an early diagnosis of infected hemothorax by symptoms and physical signs alone and the advantage of instituting early treatment made it desirable to aspirate every case of hemothorax for diagnostic purposes. Aspiration may be done the day following the injury and as often thereafter as seems indicated, and should invariably be done when some new event, as secondary rise in temperature, appears. Only a small syringeful of blood need be withdrawn, which is immediately cultured by the bacteriologist. Under the usual aseptic precautions the procedure is harmless and may be made quite painless.

Aspiration for Treatment.—The urgent and sometimes fatal symptoms associated with mediastinal and cardiac displacement (dyspnea, cyanosis, tachycardia) seen in the cases with large hemothorax require immediate aspiration for their relief. They usually appear on the day of or the day following the injury, when aspiration, because of the danger of continued or renewed hemorrhage, is undesirable. Two procedures are possible: (1) To remove by single or repeated aspirations just enough fluid to relieve the pressure symptoms. This is the procedure we adopted, and with eminently satisfactory results. It was rare that more than two aspirations of 500 c.c. of blood were necessary. (2) To remove as large an amount as possible, replacing the aspirated blood by an equal volume of air or oxygen. The procedure has the advantage that the artificial pneumothorax keeps the lung compressed and so tends to control bleeding. We have had no personal experience with the method, but a survey of the literature shows that English, French, German, and Italian surgeons have used it with good results and apparently without danger.

Aspiration is also desirable as an aid in the treatment of hemothorax in the absence of compression symptoms. It is the general experience that the blood in moderate and massive grades of hemothorax is absorbed slowly, and that as a result of this delayed absorption there occurs a retraction of the chest, thickening of the pleura, and fixation of the diaphragm by adhesions. To aid absorption or actually to remove all unclotted blood by aspiration so as to give the lung an opportunity of early expansion has been advocated and practised by the majority of authors. The time and method of aspiration has been the subject of much discussion.

It is generally agreed that to remove the blood by early aspiration and thus allow the lung to expand is to encourage continued or renewed bleeding, and efforts to obviate this danger have given rise to three procedures: a late aspiration done after the expiration of at least ten days; an earlier repeated aspiration of relatively small amounts of blood (250 to 500 c.c.), beginning on the fourth or fifth day; and an

early total aspiration combined with artificial pneumothorax. The first has the obvious disadvantage that considerable change in the pleura and diaphragm may take place before aspiration is done; the second, that of a repeated procedure with its attendant discomfort to the patient; and the third, that of requiring more apparatus and expert knowledge. In our opinion the second or third procedure are the methods of choice. Bastianelli[3] reports 206 cases of closed thorax treated by the last method, with only 7 deaths.

FIG. 342.—PYOHEMOTHORAX DUE TO GAS BACILLUS (WELCH) INFECTION FOLLOWING A PENETRATING WOUND OF THE THORAX.

The lung on the right side is almost completely collapsed. The costodiaphragmatic angle is obliterated. The large cavity has been sterilized and the sinus closed by secondary suture. Patient under observation three months, during which time the sinus remained closed, but the lung had only slightly expanded. Seen eight months after injury the lung had completely expanded. See Fig. 343. (Author's series.)

Thoracotomy for Hemothorax.—The disadvantages of aspiration in the treatment of hemothorax are that it is incomplete and fails to remove the clotted blood and fibrin in the costodiaphragmatic sulcus, and that it fails partially or completely in the cases of partially or massively clotted hemothorax. A number of authors have, therefore, advocated thoracotomy in the treatment of hemothorax, especially in those cases in which aspiration fails. The chest is opened widely by rib resection or intercostal incision, the unclotted and clotted blood completely removed, the pleura washed or wiped out, and the chest wall

immediately and completely closed. The procedure certainly has a very limited field of application. Cases of massively clotted hemothorax are rare. The general results of aspiration in the treatment of hemothorax are too satisfactory to warrant the much more formidable procedure.

Treatment of Infected Hemothorax.—In the presence of infected hemothorax established by cultures of aspirated fluid two forms of treatment have been used: (1) repeated aspiration until recovery or the development of a frank empyema demanding rib resection and

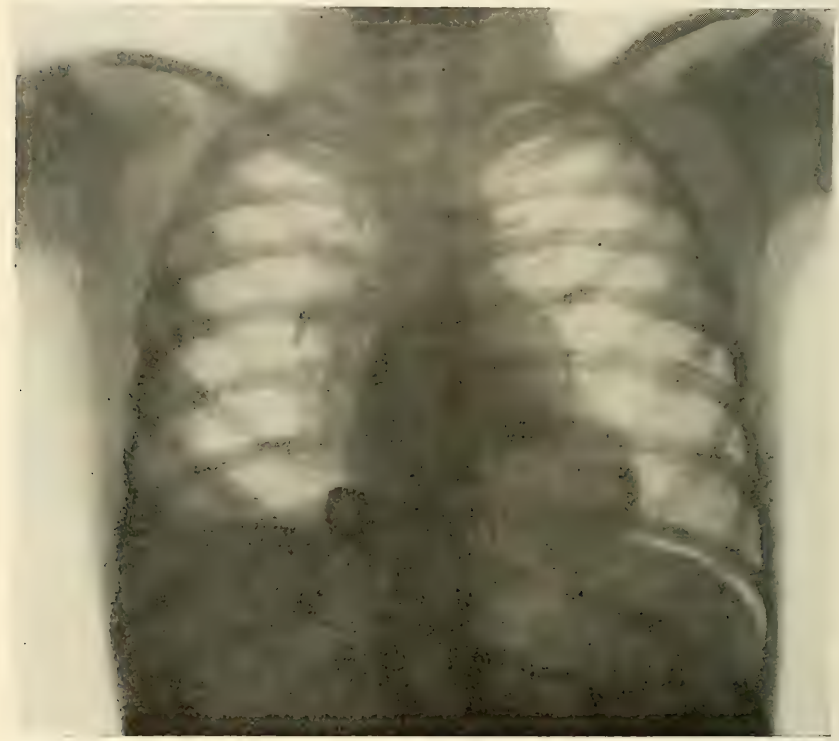


Fig. 343.—*x*-Ray of Same Patient as Shown in Fig. 342 Taken Eight Months After Injury. The right lung completely fills the thoracic cavity. The obliteration of the costodiaphragmatic angle persists. (Author's series.)

drainage; or (2) immediate rib resection and drainage so soon as the diagnosis is made. The former method of treatment has little to recommend it. Only in the mild types of infection may improvement be expected by aspiration, and often, as in the single case we have observed, convalescence is unsatisfactory and prolonged. To wait for a frank empyema to develop before operating, as suggested by German writers, is to encourage the development of serious complications, such as bronchopneumonia, pericarditis, contralateral pleurisy, or septicemia. In the severe types of infection due to the streptococcus, staphylococcus, gas bacillus, or their combinations immediate rib resection with drainage so soon as the diagnosis is established is the only proper method

of treatment. In my own entire series of infected hemothorax no accident of any sort has followed the immediate opening of the thorax. The procedure should be carried out under local anesthesia. The postoperative pneumothorax can be satisfactorily met by a properly fitting drainage apparatus. The subsequent treatment consists of irrigations of the cavity with Dakin's solution until sterilization of the cavity, as proved by culture, has been accomplished. The tubes are then removed and the sinus tract is either allowed to close spontaneously or is closed by secondary suture, leaving a closed cavity which subsequently becomes obliterated by expansion of the lung (Figs. 342, 343). This subject will be further discussed in dealing with empyema.

PNEUMOHEMOTHORAX

The association of air or gas in conjunction with blood in the pleural cavity is seen in shell explosions, contusions of the thorax and penetrating wounds, and in hemothorax infected by anaërobic organisms. In the former group air enters the pleural cavity from the injured lung or bronchi or through the parietal wound; in the latter gas is generated by the anaërobic organisms.

The incidence of pneumohemothorax depends very largely upon the type of the wound and the time at which examination is made. It is invariably present in open "sucking" chest wounds, a type which is seen at forward hospitals in from 10 to 25 per cent. of the cases (25 per cent. in our own series). In association with closed chest wounds it has varied from 2 per cent. in Bradford and Elliott's[6] cases to 47 per cent. in Piéry's[85] series. Statistics gathered from autopsy records[52] show that 12 per cent. of the cases dying of chest injuries have a pneumohemothorax; those from *x*-ray studies[13] show approximately the same percentage. The wide variation in the incidence of the condition is readily understood and depends upon the time at which examination is made. Picqué and Dupérié,[84] examining their cases early, found a pneumohemothorax in 62 per cent.; the same cases examined some days later showed this condition in but 7 per cent. as a result of the rapid absorption of the air.

The amount of air in the thorax varies again with the type of wound. In the open chest wounds air enters with each inspiration and is forced out of the thorax with each expiration. In closed chest wounds the collection of air may be small or large, occupying the greater portion of the thoracic cavity.

With regard to the lung the associated changes are the same as in the pure type of hemothorax. It undergoes collapse of varying grade, which depends upon the amount of blood and air in the contained thorax. Compression symptoms due to displacement of the heart and mediastinum may develop either slowly or rapidly, and are common, in our experience, in cases of pneumohemothorax due to the production of gas by anaërobic organisms. A distention pneumothorax due either to a valve-like opening in the chest wall or to a valve injury of a bronchus may rapidly cause death unless prompt measures are undertaken to

combat the condition. The cytologic changes in the fluid, the late associated changes in the pleura, diaphragm, and chest wall are the same in this condition as in pure hemothorax. The course of the condition depends upon the parietal wound. In the closed wounds the entrance of air into the pleural cavity is spontaneously checked, and the contained air quite rapidly absorbed. In the open sucking pneumothorax, however, the course of the condition is always serious. The physiologic disturbances due to displacement of the mediastinum give rise to cyanosis, tachycardia, and dyspnea, which lead to death in a large proportion of cases unless the external chest wound is closed. Late or secondary pneumothorax in association with hemothorax has been observed, but is rare.

Just as in the pure hemothorax, the complication to be feared in hemopneumothorax is infection. In open chest wounds it invariably occurs unless the open wound is promptly closed. In closed wounds the incidence of infection is higher than in the simple pure hemothorax.

Symptoms and Physical Signs.—These depend largely upon the type of the wound. In open thorax the symptoms are always urgent. Anxiety, restlessness, cough, hemoptysis, a high grade of shock with imperceptible pulse and low blood-pressure, cyanosis, pallor, and dyspnea are common. With each inspiration air enters the thorax, with each expiration air and often blood are ejected from it. The physical signs in these cases are practically valueless. In hemopneumothorax associated with closed chest wounds the symptoms are less urgent and, in general, are similar to those of simple hemothorax. The physical signs are retraction and immobility of the chest, dulness and enfeebled breath sounds over the fluid area, and a varying grade of tympany with absent breath sounds over the contained air. Fluoroscopy with the patient in the erect position shows a definite fluid level which is characteristic of the condition (Fig. 341).

Treatment.—The treatment of the condition requires no special comment. The same lines of treatment outlined for hemothorax apply here as well. Compression symptoms due to the rapid accumulation of blood and air require immediate aspiration. The later appearance of these symptoms combined with the physical signs of an acute pneumothorax almost invariably means infection by anaërobic organisms, a condition which demands immediate rib resection and drainage. In sterile closed pneumohemothorax without compression symptoms the air is spontaneously absorbed in the course of five or six days. The fluid may be treated by aspiration as outlined under Hemothorax.

PNEUMOTHORAX

The presence of air alone in the pleural cavity in injuries to the thorax is quite rare. In our personal series of 160 cases we have seen but 3 undoubted instances. Elliott, in a series of 170 chest wounds, has seen 6 cases. In 500 chest wounds reported by Bradford[7] there were 12 which possibly could be interpreted as simple pneumothorax, but in only 4 was it positively demonstrated. In 100 autopsies per-

formed by Henry and Elliott[52] there was no case of simple pneumothorax without effusion. Crymble,[13] in 211 cases studied by *x*-ray examination, found 7 cases of pure pneumothorax. It would seem doubtful that air in the pleural cavity without the association of blood was of common occurrence in war injuries. The air enters the thoracic cavity either through the external wound or from the wounded lung or bronchi. The lung undergoes collapse, which may be partial or complete. Compression symptoms may ensue, requiring aspiration for their relief. As a rule, however, the air is quickly and spontaneously absorbed. An associated pleural effusion is not uncommon. The chief complication to be feared is infection.

Symptoms and Diagnosis.—In closed wounds in which a moderate amount of air enters the pleural space there is an increase in the frequency and depth of respiration and slight cyanosis and tachycardia. Pain and cough may be present. The temperature at first may be slightly elevated, but in the absence of concomitant infection rapidly returns to normal. The physical signs are hyperresonance on percussion and absence of the normal respiratory sounds, and, on auscultation, voice transmission and fremitus. Fluoroscopic examination or *x*-ray plate shows the lung collapsed against the mediastinum.

Treatment.—The moderate grades of pneumothorax undergo spontaneous absorption and require no special treatment. In the presence of compression symptoms aspiration of the contained air may be necessary. The pleural effusion which so often follows pneumothorax may require aspiration. Infection, as determined by clinical signs, symptoms, and cultures, should be treated as described under Hemothorax.

CHYLOTHORAX. CHYLOHEMO- AND CHYLOHEMOPNEUMOTHORAX

These conditions result from thoracic injuries with laceration or rupture of the thoracic duct. They are seen in association with fracture of the ribs, spine, or clavicle, contusions and penetrating wounds of the chest, and suppurative diseases in the thorax. The conditions are rare. Kirchner[60] in 1885 could find only 11 reported cases, and of these only 2 could be definitely classified as of traumatic origin. Zesas[118] in 1912 collected 24 non-operative injuries of the thoracic duct, 18 of which were due to penetrating injuries. In the past war we have been able to find only 7 reported instances of chylothorax,[66, 37, 41] 6 of chylohemothorax, and 1 of chylopneumothorax. Two cases reported by Elliott and Henry[37] were the only ones seen out of 600 samples of hemothorax fluid examined. Due to the close anatomic relationship existing between the thoracic duct and the right pleura the chyle escapes, in the majority of cases, into the right pleural cavity. It has, however, been observed upon the left side, and in 3 cases has been bilateral. The amount of fluid which may escape has varied. In a case reported by Dietze[23] 27 liters of chyle were aspirated within a period of thirty-one days.

Symptoms and Physical Signs.—Injury to the thoracic duct itself does not give rise to striking or characteristic symptoms, and the

concomitant injury is the dominant feature immediately following the accident. In the further course of the condition and in the absence of infection more or less characteristic symptoms and physical signs may present themselves. The fluid in the chest, which may be either pure chyle or mixed with air and blood, may steadily accumulate, rising day by day to a higher level, and may eventually give rise to compression symptoms, with dyspnea, tachycardia, and cyanosis. The thorax may become bulgy. With the gradual accumulation of fluid there may be thirst and loss of weight. Fever in uninfected cases may be absent, and is not high even in the presence of infection because of the impairment in the patient's nutrition. The physical signs are those of fluid or a combination of fluid and air. Fluoroscopic examination shows the usual shadow due to fluid, or if air is present will show the characteristic fluid line with the patient in the erect position. Aspiration of the fluid is the surest diagnostic measure. The aspirated fluid if unmixed with blood may be clear, serous, and of a pale yellow color or a milky white. If mixed with blood it may be pinkish and resemble the fluid obtained in infected hemothorax. Microscopic examination of the fluid shows an absence of cellular elements and the presence of numerous small droplets in molecular motion. Stained with Sudan III these droplets stain an intense red and are soluble in ether. On centrifugalization the fluid may separate into three layers—a lower layer of blood, a middle layer of milky fluid, and an upper thin layer yellowish in color.

Differential Diagnosis.—A positive diagnosis of chylothorax is possible only by examination of the aspirated fluid. The presence of a milky fluid or a pinkish fluid resembling that of infected hemothorax and unassociated with fever or other clinical or cultural evidence of infection should arouse a suspicion of chylothorax. Of the 2 cases reported by Elliott and Henry, one was operated upon for a supposed infected hemothorax, and in the case reported by Frohman a similar mistake was nearly made. As mentioned by Brewer in Volume III of this work, a fluid found in the chest in certain forms of malignant disease may often resemble chyle both in its milky appearance and in the fact that under the microscope fat globules are demonstrable.

Prognosis.—In Zesas' 24 cases death occurred in 12, or 50 per cent. In 49 cases of operative injuries to the thoracic duct collected by the same author there were 5 deaths, a mortality of 10 per cent. In the 7 cases reported from the war just past 2 patients recovered and 5 died.

Treatment.—This may be expectant combined with aspiration or, if necessary, operative. Of the cases reported from the past war one was operated upon for a supposed infected hemothorax and the pleural cavity was drained, but there was no attempt made to treat the wounded duct. The patient recovered after a prolonged convalescence. In a second case the fluid became infected, necessitating rib resection and drainage, with ultimately a fatal result. A third case was treated by repeated aspiration, with complete recovery. Brewer states that repeated aspirations have been followed by cure in a number of instances. With regard to operative treatment the various procedures suggested

by Fay[39] would be extremely difficult of application in wounds of the thoracic portion of the duct and should be considered only when simpler methods have failed.

CHOLETHORAX, CHOLEHEMOTHORAX, CHOLEHEMOPNEUMOTHORAX

The conditions are extremely rare and are seen in the right-sided combined chest and abdominal wounds with injury to a large bile-duct. We have found only one case reported in war literature,[36] in which at the third aspiration a large quantity of pure bile was withdrawn from the thoracic cavity. The patient recovered without operation. The condition, because of its rarity, has little interest. The symptomatology and clinical signs are those which we have discussed in connection with fluid in the thorax. The treatment is by aspiration, unless infection occurs, necessitating rib resection and drainage.

RUPTURE AND LACERATION OF THE LUNG; HEMORRHAGIC INFILTRATION OF THE LUNG

The pathologic conditions are usually seen in conjunction with injuries to the lung by shell explosions, contusions of the thorax, and

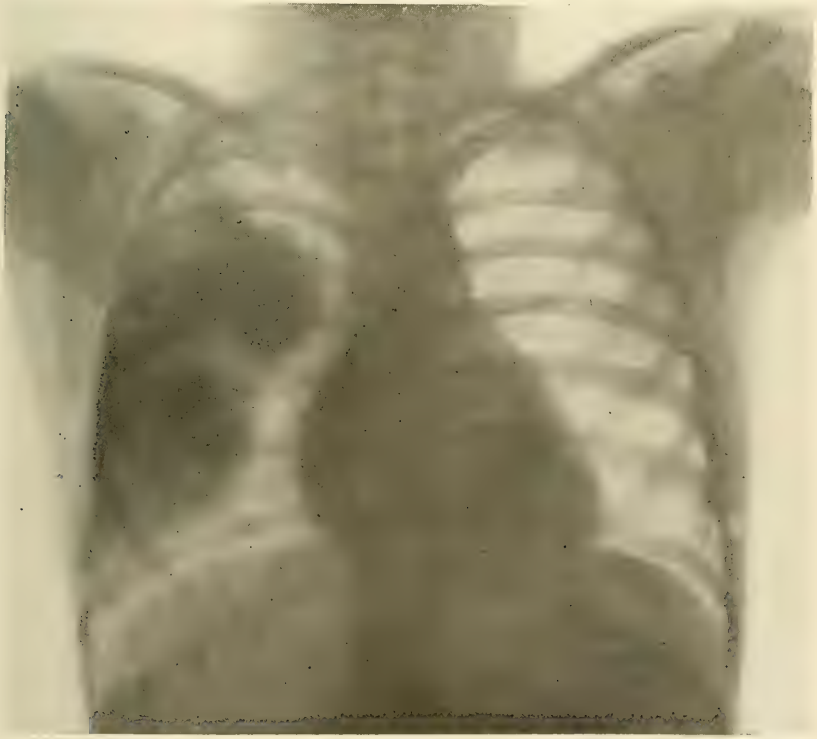


Fig. 344.—Hemorrhagic Consolidation of the Lung Following Severe Contusion of the Thorax.

The areas of consolidation appear in the *x*-ray as shadows. (Author's series.)

non-penetrating and penetrating wounds. In contusions of the thorax,

however, hemorrhagic infiltration may occur in the absence of wounds of the lung. The area involved may be either directly beneath the external injury, or even in the opposite lung. It is dark red in color, voluminous and solid, and on section resembles an infarct. Microscopic sections show the alveoli filled with blood. Clinically the condition may be recognized by hemoptysis, by the signs of pulmonary consolida-

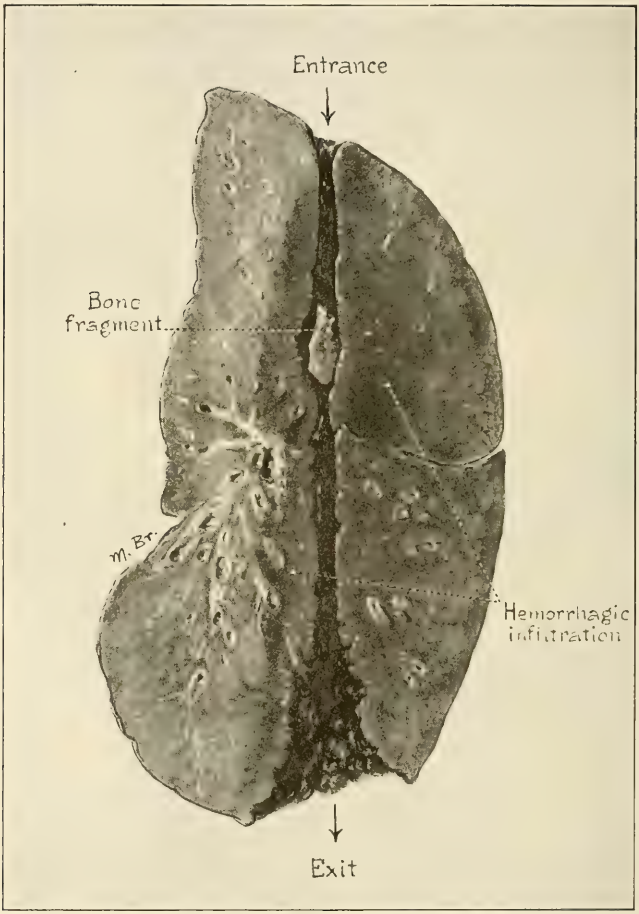


Fig. 345.—Section of Lung Showing the Wound Tract Surrounded by a Zone of Hemorrhagic Infiltration.

A bone fragment has been carried into the lung and lies in the tract.

tion, and by areas of increased density in the *x*-ray plate (Fig. 344). Rupture of the lung as seen in shell explosions is usually slight and consists of a small irregular laceration of the parenchyma surrounded by a zone of hemorrhagic infiltration. In wounds of the lung by bullet or shell fragment the extent of the injury depends upon the size and velocity of the missile and the concomitant injuries to the bony thorax. The simple perforating bullet wound of the lung may be quite small,

without laceration of the parenchyma, and surrounded by only a narrow zone of hemorrhagic infiltration. In contradistinction to these the large shell fragments, carrying with them fragments of bone, cause extensive laceration of the lung and even rupture or fracture of the parenchyma with detachment of portions of lung tissue. If the tract of one of these wounds is examined (Fig. 345) there is seen lining it a zone of cellular necrosis surrounded by an extensive area of hemorrhagic infiltration. Clothing and fragments of bone may be found in the depths of the wound.

Complications of Lacerated Wounds of the Lung.—The lung appears to be very tolerant of injury and the vast majority of wounds by small missiles heal kindly. The extensive lacerated wounds containing infected foreign bodies are more prone to infection. It may develop around the foreign body and spread along the wound tract, giving rise to an infected hemothorax, or it may become localized and form a pulmonary abscess, or manifest itself as a septic bronchopneumonia. Late hemorrhages may occur as a result of these infectious processes.

COLLAPSE OF THE LUNG—UNILATERAL OR BILATERAL

This interesting condition, described by Pasteur[79] in connection with abdominal lesions, has been especially emphasized by British authors in war wounds of the thorax. It is not the simple collapse due to the pressure of accumulating fluid, but a condition of collapse which is out of proportion to the amount of fluid present; or which takes place in the absence of fluid or air in the pleural cavity. It is seen in contusions and in non-penetrating and penetrating wounds. It may involve a part of a lobe, a lobe, or, in the so-called massive collapse, the entire lung; and with reference to the injury, may be homolateral, bilateral, or contralateral. Most commonly the lower lobe on the injured or opposite side is affected. The condition is seen early and spontaneously disappears within the first week after the injury, but according to Bradford[8] may persist for three weeks. According to this author the clinical signs are quite characteristic. The chest on the affected side is retracted and immobile, the heart displaced toward the collapsed lung, and the diaphragm high and immobile. The auscultatory signs may be divided into three periods, in the first of which there is either weakness or absence of breath sounds over the affected area; in the second, tubular or amphoric breath sounds, and in the third, accompanying râles and crepitations. In massive collapse the chest on percussion may be dull to the clavicle and the signs resemble those of a massive hemothorax, but without a similar displacement of the heart. The *x*-ray appearances are opacity of the affected lung, elevation and immobility of the diaphragm, and displacement of the heart toward the collapsed lung. The frequency of the condition in injuries of the chest is unknown. Soltau and Alexander[104] noted it in 48 per cent. of their cases. Crymble,[13] in 211 cases studied with the *x*-ray, observed 15 cases, 5 of which were homolateral and 10 contralateral. Its course is favorable. Its importance lies in the facts that it may be confused with

pneumonia and that when contralateral and extensive may contraindicate operative procedures. The causes of its production are largely conjectural. The most plausible explanation is that the bronchus is occluded by a blood-clot and the lung distal to the occlusion collapses due to the absorption of air in its alveoli.

POSTTRAUMATIC PNEUMONIA

It is extremely difficult to form any accurate estimate of the incidence of posttraumatic pneumonia in wounds of the thorax, for undoubtedly many errors were made in the interpretation of the physical signs. In the early stages of the war the cough, blood-stained sputum, fever, areas of dulness, tubular breathing, bronchophony, and whispered pectoriloquy seemed to justify the diagnosis of pneumonia, but undoubtedly were often due to simple hemothorax. Similar signs and *x*-ray examinations led to the diagnosis of pneumonia when hemorrhagic infiltration of the lung was the actual lesion. Areas of congestion with fever and blood-stained sputum also gave rise to errors in diagnosis. As one reads the literature he finds that there are two groups of observers—those (the minority) who think pneumonia is relatively common, and those (the majority) who have found it rare. To the first group belong Piéry[85] and his followers, who find that practically all penetrating war wounds are accompanied by a symptom-complex, the "syndrome hémopleuropneumonique," characterized anatomically by hemothorax plus pneumonia. Von der Velden[112] and Shreyer[102] found it in from 30 to 40 per cent. of their German wounded; on the other hand, Maisonnet,[72] Weis,[114] Barthélemy,[2] Ehret,[34] Soltau and Alexander,[104] Toenniessen,[108] Rees and Hughes,[89] Howard,[55] and Henry and Elliott[52] have found it in less than 3 per cent. among French, British, and German wounded. Autopsy records show a relatively small number of cases of true pneumonia and support those who believe in its infrequency. Grégoire and Courcoux[47] point out that the appearance of the wounded lung has led to the belief that the condition was a traumatic pneumonia; but secondary infection, which often appears to be the cause of hepatization in the infarcts of Laënnec, is not found in the traumatic hematomata in pulmonary injuries. The lesions about the hemorrhagic zone are rather of the nature of congestion. The alveoli, perfectly distinct in outline, show desquamating endothelial cells mixed with leukocytes and red cells, but without a fibrinous reticulum and without an organized exudate. A true pneumonic area, in their experience, is never found. In our personal series of 160 cases lobar pneumonia was found at autopsy once and bronchopneumonia seven times, in one of the latter associated with septicemia and infarct. Four other cases which recovered were thought to have had areas of bronchopneumonia.

Pneumonia, although perhaps rare, is one of the serious complications of pulmonic injuries. It occurs as a lobar type, apparently only in the lung opposite to the injury, and as a septic bronchopneumonic type, either in the lung injured—the process starting usually in the

neighborhood of the wound—or in the opposite uninjured lung in an area of hemorrhagic infiltration. It may be associated with septicemia and septic pulmonary infarct. The diagnosis may be extremely difficult, for, as previously noted, the physical signs are common to hemothorax, hemorrhagic infiltration and congestion, and collapse of the lung. Only when it occurs late or in the opposite lung unassociated with other complications may an accurate diagnosis be made. The *x*-ray is not especially helpful. The course is toward resolution in the vast majority of cases. The treatment requires no comment.

ABSCESS OF THE LUNG

The available literature upon the subject would indicate that the condition, as a complication of penetrating wounds, is very rare. In the statistics which we have consulted it has occurred in less than 1 per cent. of the cases. In our personal series it has occurred in 1.2 per cent.

Abscesses of the lung in association with penetrating wounds may occur early or late. They invariably develop about an infected foreign body, either shell fragment, bullet, bits of clothing, or of bone. The infection becomes localized by the collapse of the wound tract, giving rise to a cavity filled with pus and containing the foreign body and lined by a greenish-gray necrotic wall, around which is a zone of consolidation. Grégoire and Courcoux[47] divide abscesses due to penetrating wounds into the early or gangrenous and the late or phlegmonous abscesses. The former develop within the first two or three weeks following the injury, are rarely larger than an egg or orange, have a grayish-green irregular wall, and a cavity filled with débris of pulmonary tissue. The foreign body lies free in the cavity. Vessels resistant to the infection may cross it, but later may give rise to secondary hemorrhage. A zone of consolidation of varying depth surrounds the abscess wall. The pleura may become involved, the abscess rupturing into it, or adhesions may form and obliterate the parietal and visceral pleuræ.

The phlegmonous abscesses occur after weeks or months. They may at first be very insidious and then suddenly present signs of severe infection, or they may give rise to no symptoms throughout their course, and be an unexpected finding during the late extraction of foreign bodies. They are usually small in size. The cavity is rarely regular, is filled at first with thick pus that drains with difficulty, but which later becomes more fluid. The foreign body occupies the center of the abscess. They tend more often to work to the surface than to open into a bronchus, and they may rupture and form an hour-glass abscess under the ribs.

Symptoms.—The symptoms are indefinite and insidious. Sometimes an abscess is indicated by a recrudescence of the fever, by vague thoracic pain, and a persistent cough. Abundant expectoration with a foul odor is perhaps the most definite sign of abscess. Symptoms and signs which suggest tuberculosis—signs of a cavity at the apex, abundant expectoration, an oscillating temperature, and loss of weight—have been described. Sometimes late abscesses of the lung, undiag-

nosed during their course, become evident when expelled from a vomica through the bronchus.

Treatment.—This requires no comment. Early diagnosis, accurate localization, and drainage are the essential features.

GANGRENE OF THE LUNG

In penetrating wounds of the thorax pulmonary gangrene is even rarer than pulmonary abscess. Duval[30] and a number of other French authors have reported isolated examples of this condition; Haim[48] has reported 3 cases; and we have seen one instance in our personal series. Most interesting are the 3 cases reported by Tuffier[21] in which at operation, done for suppuration of the pleura, there were found free fragments of gangrenous lung tissue lying in an abundant quantity of foul-smelling fluid.

In penetrating wounds of the chest two types of gangrene were seen, a gangrene associated with infection—as seen in civil life—and a true gas gangrene of the lung due to virulent, gas-forming anaërobic organisms. The former variety was by far the more common and requires no special comment. True gas gangrene of the lung was extraordinarily rare, but a few instances have been noted in the literature (Duval,[30] Lockwood[65]). It has been well described by Grégoire and Courcoux.[47] Briefly, the infection begins early, within the first twenty-four hours after injury, and is accompanied by high fever, rapid, thready pulse, low blood-pressure, cyanosis, anxiety, restlessness, and delirium. The physical signs are not characteristic. Exploratory aspiration may show malodorous bloody fluid which leaves no doubt as to the type of infecting organism; but such characteristic fluid may be absent in some cases. In 2 cases Duval has been able to demonstrate the anaërobes of gas gangrene in the sputum. Autopsy commonly shows the pleural cavity more or less filled with a foul bloody fluid, and the lung, for a variable distance around the wound, deep red or black, gangrenous, and spongy with the infiltrated gas. The diagnosis may be difficult in some cases. The fetor of the breath is not necessarily a pathognomonic sign of gangrene and may be associated merely with the elimination by the bronchus of necrotic tissue from the wound in the lung. The treatment of gas gangrene of the lung is unsatisfactory. The infection is invariably fatal, and usually within thirty-six to forty-eight hours. In one case recorded in the literature excision of the lung was attempted, but with a fatal result.

CONTUSIONS OF THE THORAX

The subject has been covered by Dr. Brewer in Volume III. The milder grades of injury need not again be referred to. In the severer injuries seen in the past war due to blows from swiftly moving objects, burying accidents and aëroplane crashes some new conditions due to injury of the intrathoracic viscera have been observed and perhaps warrant mention. Hemothorax and its related conditions, rupture or laceration of the lung, injuries to the diaphragm, pleural effusion, and various infectious complications were commonly seen. Among the more

interesting conditions hemorrhagic infiltration of the lung, as described in preceding pages, was not an uncommon finding. The involved area lay either directly under the pole of impact, or at some distance from it, or in the opposite lung, was apparently the result of trauma by contrecoup, and was sometimes associated with a homolateral or contralateral hemothorax. In the presence of fever, cough with blood-stained sputum, and the signs of consolidation this condition must previously have been often wrongly diagnosed pneumonia. Rapidly forming filmy adhesions, traumatic in origin, between the pleuræ of the opposite side have been an autopsy finding and perhaps explain the friction-rub sometimes found on the side opposite the injury. Collapse of the lung, either unilateral, bilateral, or contralateral, has been an interesting finding which has been confirmed by *x*-ray, operative, and autopsy observations. Rupture of the pericardium with the development of a hemopneumopericardium was observed in one of our cases of severe contusion. In the low thoracic injuries hemorrhagic infiltration of the liver and spleen analogous to the condition in the lung has been observed, giving rise to abdominal pain, hiccup, vomiting, and rigidity. The high position and immobility of the diaphragm seen in association with the intrathoracic injuries following contusions has been one of the most interesting *x*-ray findings.

Treatment.—The treatment of the mild injuries need not be referred to. In the severe injuries absolute rest in bed, morphin sufficient to induce quiet, and energetic measures to combat shock are the important first steps in treatment. The later treatment is expectant. Hemoptysis tends spontaneously to cease. Fractures of various bones should be immobilized by proper fixation. Strapping in some of the comminuted rib fractures has, in our experience, been uncomfortable rather than comfortable, due apparently to the pressure of fragments against the lung. An accurate diagnosis of the intrathoracic condition should be made as early as possible. A small hemothorax may be left untreated and may be expected to be absorbed spontaneously. The moderate and high grades should be aspirated as described under Hemothorax; and continued hemorrhage—indicated by a rapidly mounting fluid level and signs of anemia—may be treated by aspiration combined with artificial pneumothorax. Thoracotomy for alarming hemorrhage has not been indicated in our experience. Compression symptoms due to hemo- or hemopneumothorax should be treated by aspiration and enough fluid should be withdrawn to relieve the symptoms. A distention or valve pneumothorax due to laceration of a bronchus has not been observed by us, but is conceivable, and must be treated by pleural puncture. Subcutaneous emphysema, often extensive, spontaneously disappears and requires no treatment. The pulmonary lesions, such as hemorrhagic infiltration, collapse, and the posttraumatic pneumonias, require no active treatment aside from general measures. Infection of the pleura, diagnosed by symptoms or, more surely, by cultures from aspirated fluid, should be treated by rib resection and drainage, with subsequent sterilization of the cavity as described under Empyema.

The occurrence of abdominal pain and rigidity, hiccup, and vomiting may indicate rupture of the diaphragm or of an abdominal viscus; but in our experience a waiting policy has been rewarded by the disappearance of the symptoms. In the absence of fluid, rupture of the diaphragm with prolapse of the viscera through the defect may be seen by fluoroscopy, as in one case observed by Guthrie. The treatment of such diaphragmatic herniæ is rather by thoracotomy, with reduction of the prolapsed viscera and closure of the diaphragm, than by laparotomy, as suggested by Brewer.

WOUNDS OF THE THORAX

For purposes of classification we may divide wounds of the thorax into non-penetrating and penetrating wounds. By the former we mean those in which the parietal pleura is not opened; by the latter, those in which it is opened. The differentiation is not always easy, for almost all the conditions which we see in the penetrating type may be present in the non-penetrating variety.

Non-penetrating Wounds.—For the general treatment of this subject reference may be made to Volume III. Only the non-penetrating wounds seen in the past war need be considered here. They were caused by rifle bullets, shell fragments, shrapnel balls, and bayonet thrusts, the frequency of each variety depending upon the character of warfare. Wounds by shrapnel ball, compared with bullet and shell wounds, were infrequent, and bayonet wounds were quite rare. Every part of the thorax was involved, and the character of the wounds, their course, and the point of lodgment of foreign bodies were subject to the greatest variation. In general, we may differentiate between the perforating or seton wounds (among which may be included the questionable group of contour wounds) and the penetrating wounds with retained foreign bodies. The severity of both types depend upon the character and size of the missile and associated fractures. When caused by small projectiles and in the absence of fractures, the wounds in general are small, with a moderate hemorrhage and destruction of tissue. When due to large missiles the wounds are large, lacerated, and accompanied by great destruction of tissue. Associated fractures of the bony thorax always cause a more serious injury because of the laceration of the tissue by fragments of bone. In general, bullet wounds are the most benign and are least prone to subsequent infection. Evidences of explosive action at the wound of exit are not uncommon in this type.

The associated fractures are those of ribs, scapula, clavicle, sternum, and vertebræ. Both simple and comminuted fractures of the ribs are seen, but the latter rarely in non-penetrating wounds, because comminution is so often associated with laceration of the parietal pleura. Fracture of the scapula is of common occurrence, as are fractures of the spines and transverse processes of the vertebræ. The clavicle and the sternum escape to a surprising degree, and in our entire experience of penetrating and non-penetrating chest wounds we saw but one fracture of each bone.

The non-penetrating wounds may further be classified as simple wounds unassociated with intrathoracic lesions, and complicated wounds with intrathoracic or intra-abdominal injury. The latter group, if due to contusion of the intrathoracic structures, may be accompanied by hemoptysis, hemothorax, hemorrhagic infiltration, and collapse of the lung; or, if due to contusion of the upper abdominal viscera, by hemorrhagic infiltration of the liver and spleen, or rupture of these organs, with bleeding into the peritoneal cavity.

Diagnosis.—The differential diagnosis between non-penetrating and penetrating wounds is usually, but not always, easy. It has been no uncommon experience to operate in the absence of all signs of intrathoracic injury and to find on opening the wound a comminuted rib fracture with laceration of the parietal pleura and injury to the underlying lung. In the majority of cases, however, the direction and course of the wound, the *x*-ray findings, and the absence of symptoms and signs of intrathoracic injury will lead to a correct diagnosis. Subcutaneous emphysema, as is well known, is not pathognomonic of penetrating wounds, and may be caused, in the absence of an open pleura, by the movements of the thorax; while in penetrating wounds it is commonly absent.

Prognosis.—The prognosis of non-penetrating wounds is favorable. Serious hemorrhage is rare and shock infrequent in the milder grades of injuries. We have seen two instances of laceration of the brachial artery—one associated with an enormous hematoma and fatal shock, the other resulting in an aneurysm presenting under the pectoral muscle which was successfully treated by ligation. Gas infection with gangrene, the most feared complication in all war wounds, is rather uncommon in wounds of the thorax, and in only one instance in a series of several hundred cases have we seen a true gas gangrene develop in a thoracic wound.

Treatment.—Even in the past war, where all wounds were considered infected, the clean perforating bullet wounds with small wounds of entrance and exit were quite benign and, as experience in times of great press of work showed, healed aseptically without operation in a large proportion of cases. Sterilization of the skin about the wound and the application of a sterile dressing sufficed. The potential danger of infection is nevertheless present, as we have repeatedly demonstrated by finding bits of clothing and other infected material in these wounds. The penetrating wounds, with retained foreign bodies, and the perforating shell, shrapnel, or bullet wounds, with fractures and laceration of tissues, all require operation. Experience showed that the danger of infection is too great to warrant expectant treatment. Shock in the seriously wounded may delay the time of operation, but, in general, it should be undertaken as soon as possible. The operative procedure consists in the various steps included under the term "débridement"; that is, excision of the wound of the skin, of the traumatized subcutaneous tissues, of all lacerated muscle down to actively bleeding and normal appearing tissue, removal of bone fragments if a fracture

is present, and removal of the foreign body with a surrounding zone of tissue. The wound may be closed immediately by primary suture or left open, to be subsequently closed by retarded primary or secondary suture. The success of primary suture depends upon various factors, such as the age of the wound, the presence of obvious infection, the extent of the laceration of the tissues, but chiefly on the accomplishment of a thorough débridement. If primary suture is done, hemostasis should be painstaking, the divided muscles and nerves resutured, and the skin closed without too great tension. It is important to attempt primary suture in wounds complicated by fracture in order to avoid subsequent infection, and especially important in the wounds with rib fractures, failure to close which may result in a secondary infection involving the pleura. That primary suture is possible in a large proportion of the cases is shown by our statistics—90 per cent. of the wounds about the thorax were closed by primary suture with less than 5 per cent. of failures. Wounds left open because of loss of tissue, gross infection, or failure to do a thorough débridement may subsequently be closed by retarded primary or secondary suture, according to the now well-known methods. If in the course of an operation done for a non-penetrating wound a comminuted rib fracture with laceration and opening of the pleura is found, the fractured rib should be excised, the lung inspected for injury, any in-driven bone fragments removed, the bleeding from the lung or parietal wound controlled, the hemothorax evacuated, and the pleura, if possible, and the intercostal muscles air-tightly closed. The external wound should invariably be closed, for to leave it open is to invite infection with reopening of the pleura and the development of an open pyopneumothorax. This subject will be considered at greater length under the operative treatment of penetrating wounds.

Penetrating Wounds.—For an exposition of penetrating wounds as seen in civil life reference should be made to the chapters of Dr. Brewer in Volumes III and VI.

The penetrating war wounds have particularly interested surgeons because of their unexpectedly high mortality. In the Civil War and the War of 1870 the mortality of penetrating wounds was 62 and 53.4 per cent., respectively, due in part to the character of the missiles and the resulting large wounds, and in part to unsatisfactory methods of treatment. It dropped to 27.5 per cent. in the Spanish-American War, to 14 per cent. in the Boer War, and to 3.5 per cent. in the battle of Mukden in the Russo-Japanese War. This fall in mortality was due rather to the adoption of the high velocity, jacketed small caliber bullet than to better methods in the treatment of war wounds. Before the beginning of the Great War wounds of the chest were considered relatively benign, and surgeons of all countries advocated their conservative and expectant treatment. The first few months of the war demonstrated the fallacy of this idea. The clean perforating bullet wounds and the small shell wounds, if in association with closed thorax, still showed a relative benignancy; but the large number of wounds due to

shell fragments and to bullets with associated fractures showed a high mortality. The French, British, and German statistics show a marked similarity in the mortality rate. A considerable but unknown number died on the battlefield of hemorrhage and shock. Sauerbruch, examining 300 dead on the field, found 112, or 30 per cent., dead of wounds of the chest. From 20 to 25 per cent. of those who lived to reach the first-aid posts died there from hemorrhage, shock, and open thorax. An added 20 per cent. of those who were transferred from forward areas to evacuation hospitals or similar units died immediately of the same causes or later from infectious complications, and an additional 5 to 10 per cent. died from infection along the lines of communication or in base hospitals. Nor does this include a certain though small percentage which died late from late abscess, gangrene, and other complications. Isolated statistical papers, therefore, particularly those from base hospitals, give no accurate idea of the seriousness of penetrating chest wounds. The highest mortality occurred in the first forty-eight hours from hemorrhage, shock, and open thorax. The later mortality was chiefly due to infection. It became evident to surgeons of all countries, and at approximately the same time, that the expectant treatment of some groups of wounds of the chest was inadequate and that active surgical measures were necessary in order to reduce the high mortality. It would be difficult at the present time to place the credit for the newer conceptions in the treatment of wounds of the chest. Many of the principles had been expressed before the war, and were rediscovered and established or not through large experience. Perhaps Duval deserves the greatest individual credit, for he was the leader in the early operative treatment of injuries of the chest, and his insistence upon this treatment from the summer of 1916 on undoubtedly exerted a great influence among French, British, and American surgeons. The subsequent progress in the treatment of wounds of the chest developed along the lines of controlling immediate hemorrhage, of combating open sucking pneumothorax, of preventing early and late infection, and of devising safe methods for the late removal of foreign bodies. How greatly the mortality has been lowered is at present uncertain. Duval has made the statement that the total mortality has been reduced from 40 or 50 to 9 per cent. Certainly, in one group of cases—those with large open sucking wounds of the chest—the mortality has been lowered from 100 to 25 per cent.

Incidence.—It is difficult to form any accurate estimate of the frequency of wounds of the chest. Soltau,[105] among the British, found that from 2.5 to 3.5 per cent. of all casualties admitted to C. C. S. were wounds of the chest. Sauerbruch,[98] among 22,145 wounded, reported 936 wounds of the chest, or 3.17 per cent.; Latarjet,[62] among 9328 wounded, saw 885 wounds of the chest, or 9 per cent.; and Duval[31] states that the percentage of injuries of the chest at the forward hospitals is about 7.8 per cent.

Types of Wounds According to Missiles.—These include bullet, shrapnel, shell, and bayonet wounds. The frequency of the various

types varies greatly in different statistics according as the reports come from forward or rear hospitals. The forward hospitals saw a relatively higher percentage of shell wounds; the rear hospitals, because of the benignancy and transportability of these injuries, saw a higher percentage of bullet wounds. An average of the reports of eighteen authors taken from the literature shows 48.8 per cent. bullet wounds, 44.2 per cent. shell wounds. Shrapnel ball wounds were relatively uncommon and bayonet wounds quite rare. Very striking, as contrasted with all previous wars, is the high percentage of shell wounds. This, as we shall indicate, was in part responsible for the high mortality of thoracic injuries.

The severity of wounds according to the type of missile producing them may be gathered from the following table:

MORTALITY PERCENTAGES

Author.	Shell.	Bullet.	Shrapnel ball.
Depage[20]	40.0	17.6	28.0
Duval[28]	28.0	2.0	
Debeyre[18]	16.0	12.0	
Maillet[70]	20.5	16.0	
Schmid[100]	40.0	4.5	
Lonhard[68]	48.0	29.0	30.0
Gask and Wilkinson[42]	34.0	13.2	9.9

Similar statistics show that the penetrating wounds with retained missiles are more deadly than the perforating wounds.

Variety of Wounds.—It would take too long to describe the many varieties of penetrating wounds. They involve every part of the thorax; the missiles enter from every direction; they produce the most varied lesions. Wounds are either perforating, with an entrance and exit wound, or penetrating, with lodged missiles; and they are associated either with closed or open thorax. Their severity depends on the extent of damage to the chest wall and intrathoracic structures. That the shell wounds caused the highest mortality was due to the fact that they caused the greatest destruction of tissues, often produced an open pneumothorax, and were most prone to give rise to infectious complications. Because of the slight damage to the chest wall and lung, the clean perforating bullet wound, not complicated by fractures, was the most benign of the thoracic wounds.

The injuries to the soft parts vary from a punctured wound, with slight destruction of tissue, to large lacerated wounds, with great destruction of tissue and loss of substance. The fractures of ribs, spine, scapula, clavicle, and sternum may be slight or severe and extensively comminuted. They greatly complicate the wound, not only because of the fact of a compound fracture with its attendant danger of infection, but because of laceration of tissue, either soft parts or lung, by infected fragments of bone.

The *injuries to the lung* vary from the clean perforating bullet wound, with a minimum of tissue destruction and little bleeding, to large irregular lacerated bleeding wounds surrounded by a wide zone of

hemorrhagic infiltration. We have seen actual fractures of the lung, and separation of considerable fragments of lung tissue have been described. In association with penetrating wounds of the thorax complicating injuries as follows have been noted: injuries of the brachial plexus (in severity varying from simple contusion to actual division); of the brachial or axillary vessels with fatal hemorrhage or the development of massive hematomata or false aneurysm; of the internal mammary vessels with external or internal hemorrhage; of the heart and the great vessels of the mediastinum and hilum; of the azygos veins; of the thoracic duct with the development of chylothorax; of the spine with lesions of the cord; of the bronchi with the development of pressure pneumothorax or mediastinal emphysema; of the esophagus with pressure pneumothorax, mediastinal emphysema, mediastinal abscess, esophageal stenosis, or fistula; of the cervical sympathetics with its symptomatic triad of narrowed lid-slit, contracted pupil, and enophthalmos and of the diaphragm and upper abdominal viscera. Many have been seen in our personal experience. They affect seriously the prognosis of these wounds and are responsible for a certain, though at present unknown, mortality.

The region of the thorax involved influences the seriousness of injuries of the chest. The wounds of the central zone are especially dangerous because of injuries to the heart, great vessels, spine, and internal mammary artery. Those of the apical region are serious because of associated lesions of the brachial plexus and brachial and axillary vessels. They cause a larger hemothorax either because the collapse of this portion of the lung is late or because of adhesions which prevent collapse. They seem more prone to lung infections because of the inability of this region to collapse. The lateral or tangential wounds are grave because of extensive rib fractures and their tendency to infection. The low thoracic wounds are often associated with lesions of the diaphragm, liver, spleen or stomach, and are of the most serious type. The wounds of the central region of each half of the thorax are, in our experience, the most benign.

Pathologic Course of Penetrating Wounds.—We must differentiate at once, from the standpoint of seriousness, into penetrating wounds with open thorax and those with closed thorax. The distinguishing feature of the former is the presence of an open wound communicating with the thoracic cavity through which air enters and escapes with each respiratory movement—the so-called "sucking" wounds. In the latter the wounds of entrance or exit are spontaneously closed by the falling together of the tissues, which prevents communication of the thoracic cavity with the exterior.

Open wounds of the chest in comparison with closed wounds are infrequent. They are commonly seen in forward hospitals; rarely—because of their severity—in base hospitals. A review of the literature from forward areas shows from 10 to 30 per cent. open chest wounds. In our personal series 25 per cent. were open wounds. In a large proportion of cases they are due to shell fragments, but are occasionally

caused by bullets. In size they vary from 2 to 5 cm. in diameter. The smaller wounds are clinically less serious. They tend to close spontaneously in the course of twenty-four to forty-eight hours, and, with few exceptions, can be closed and converted into closed wounds by a pressure dressing.

The immediate result of an open wound is the entrance of air into the thorax and collapse of the lung—not total, but partial, and of the degree seen in the cadaver. There occurs an immediate alteration in the intrathoracic pressure relations. The pressure in the opened thorax is atmospheric pressure and, according to the experiments of Graham and Bell, is the same in the unopened thorax. The lung on the unopened side may then be assumed to be in a state of collapse equal to that on the opened side. This in itself markedly hinders respiration, but it is further hindered by the to-and-fro movements of the mediastinum. With each inspiration the mediastinum is displaced toward the unopened side, defeating in part as regards air intake the inspiratory effort; with each expiration it is displaced toward the open side, with diminished air expulsion. The total result of each respiration is a lessened air exchange, with an accumulation of CO_2 in the alveoli. Hemorrhage from the injured lung is a second immediate result of the injury and is likely to be severe and prolonged because the accumulating blood, so soon as it reaches the level of the open wound, escapes through it and so fails to compress the lung and check its bleeding. In large open chest wounds, therefore, we have a combination of two serious conditions—hemorrhage and disturbed respiration. It is manifested clinically by profound shock, pallor, imperceptible pulse, low blood-pressure, dyspnea, and cyanosis. The condition is usually fatal within the first twenty-four hours if unrelieved, although we have seen patients live with large open wounds for four or five days. Should the patient survive forty-eight hours the third result of such open wounds invariably manifests itself. Infection, in the experience of every surgeon, occurs in practically every case, either of the pleura alone, with a resulting pyopneumothorax, or in combination with a pulmonary infection. In the early period of the war under expectant treatment the large open wounds showed 100 per cent. mortality. Death occurred within twenty-four to forty-eight hours from hemorrhage, shock, and traumatopnea, or within four or five days from the added infection.

Closed Thorax.—The conditions are less severe than in the above group of cases. In the perforating bullet wound the immediate effects of the passage of the bullet may be almost nil. The wounds in the thorax are immediately sealed, there is little or no escape of air into the chest, little if any hemorrhage, and very little collapse of the lung. Clinically the injury causes slight dyspnea and tachycardia. With rest in bed these symptoms rapidly subside. In the severer injuries there is probably in many cases an immediate entrance of air in small amounts into the thorax either from without or from the wounded lung. If the external wound is sealed, the air is soon absorbed. Hemorrhage occurs and gravitates to the costodiaphragmatic sulcus, gradually filling the

thoracic cavity as it accumulates. The lung undergoes collapse, the degree depending on the size of the hemothorax—and perhaps to a greater extent than would be expected. With the collapse of the lung and the maintenance of the collapse by the accumulated blood hemorrhage spontaneously ceases. The mediastinum is often displaced toward the unaffected side, as indicated by the position of the apex-beat, and may be displaced so much as to give rise to pressure symptoms (cyanosis, dyspnea, and tachycardia). Simple aspiration relieves these symptoms. Generally, with the patient in bed, the respiration twenty-four hours after the injury is quiet, easy, without cyanosis, and with only moderate tachycardia. There is nothing comparable in these cases to the respiratory disturbances seen in open thorax, and but rarely the profound shock. The subsequent pathologic course is either toward recovery or toward the development of infection. In the former event the small effusions of blood are spontaneously absorbed, the lung re-expands and restoration may be complete, with the exception of a slightly thickened pleura and adhesions obliterating the costodiaphragmatic sulcus. In the larger effusions with the deposition of a thick layer of fibrin upon the visceral and parietal pleuræ absorption becomes slow and finally ceases, the fluid remaining at the same level for months, and in a few reported cases for a year. Restoration to normal is slow and never complete. There remain a retracted thorax, a thickened pleura, and a high fixed diaphragm. Months or a year or more after patients are up and about they complain of intrathoracic pain, dyspnea on the slightest exertion, and tachycardia. If, instead of taking an aseptic course, infection occurs, the pathologic course becomes grave. Infected hemothorax or pyothorax—especially serious if due to gas-forming anaërobes or streptococci—and pulmonary abscess and gangrene, often complicated by purulent pericarditis and septicemia, have been responsible for three-fourths of the deaths from simple closed chest wounds.

Symptomatology of Penetrating Wounds.—We must differentiate again between wounds with open thorax and those with closed thorax. As noted above, the pathologic conditions in the former are grave and the symptoms are correspondingly serious. In the large open wounds a profound grade of shock is the most striking feature. The patients are blanched, cold, sometimes sweating; the pulse is imperceptible or just palpable, rapid, and running; the blood-pressure is low, often below 70 mm. Hg.; there is marked dyspnea, cyanosis, anxiety, and restlessness. Cough with hemoptysis is frequent, pain is complained of either in the wound or at some distance from it. Each inspiratory effort is accompanied by the distressing suction of air through the wound. The whole picture is an alarming one. Immediate physical examination gives little information of value; indeed, is inadvisable because of the patient's serious condition. Active measures to convert the open wound into a closed one and to combat shock claim one's immediate attention.

The small open chest wounds present in general the same clinical

picture, but the symptoms are not so severe. Shock is less profound, respiratory disturbances less urgent, circulatory disturbances usually less marked. There is more often subcutaneous emphysema, which may be local or spread over the entire body. Blood may escape on expiration through the small wound. Before physical examination is attempted the wound is iodinized and covered with a firm pressure dressing, converting the open wound into a closed one.

In the closed wounds the symptomatology varies with the severity of the injury. In the through-and-through bullet wounds pain, cough, dyspnea, tachycardia, and shock may be inconspicuous. In the severer injuries there may be serious and even profound shock and severe cough, hemoptysis, pain, and dyspnea; and in the low thoracic injuries abdominal pain, rigidity, hiccup, and vomiting. In these only such immediate physical examination as can be done without disturbing the patient should be undertaken.

Clinical Course.—In the large open wounds of the chest, unless active surgical measures are taken to close the breach, the clinical course is progressively downward. Shock is not recovered from—rather, becomes more profound—and death occurs in the majority of cases in from twenty-four to forty-eight hours. Should life be prolonged for several days the eventual outcome is, nevertheless, fatal, due to infection. In the small open wounds which can readily be closed and in the closed wounds the clinical course is strikingly different. The patient, admitted in shock, presents quite a different picture after twelve to twenty-four hours' rest in bed. He is quiet, composed, his pulse has returned, his blood-pressure has risen, and his color is better. One is truly astonished at the change in his condition, and the thought invariably occurs that his previous apparently serious condition was out of all proportion to the injury and the blood lost. Slight dyspnea and tachycardia may persist for several days, cough and hemoptysis may continue for a week. Fever usually appears within twelve hours, may reach 101° to 102° F., even 103° to 104° F., may continue for a week, then gradually fall, or may persist for several weeks. Clinical examination, of little value before twenty-four hours after injury, shows a hemothorax of varying grade, or a pneumohemothorax or pneumothorax, and may show, in addition, signs of the various complications, such as hemorrhagic consolidation, pneumonia, or pulmonary collapse, which have been discussed in preceding pages. Cardiac displacement is usually present. Mediastinal compression symptoms due to a massive hemothorax may supervene and require aspiration for their relief. Complicating injuries to the spine, thoracic duct, and abdomen may be discovered. The subsequent course, in the absence of complicating injuries, depends on the presence or absence of infectious complications, to a slight extent on late hemorrhage or hemoptysis. Cases progressing aseptically recover in the course of from three to four weeks. In from 10 to 25 per cent. of the cases with hemothorax infectious complications may be expected.

Diagnosis and Differential Diagnosis.—The diagnosis of the open

penetrating or perforating chest wounds is self-evident; the diagnosis of closed penetrating wounds is usually easy. The course of the wound if perforating, the position of the foreign body if penetrating, combined with the symptoms and physical signs, will usually differentiate between the non-penetrating and penetrating wounds. Occasionally, however, the differential diagnosis between non-penetrating and penetrating wounds may be extremely difficult. After all, such a differential diagnosis is of no great importance, for practically the same indications for treatment apply to both. The prompt recognition of continued hemorrhage, of fractures, of the presence of retained projectiles, and of immediate and late complications of the wound has an important bearing on the prognosis and treatment of penetrating wounds. They have been considered in previous pages and need not again be referred to here.

Prognosis.—This has been commented upon in speaking of the seriousness of penetrating thoracic wounds. From a survey of the available literature we may make the general statement that in large open wounds of the chest the mortality, with adequate treatment, is 25 per cent., and in small open and closed chest wounds is under 10 per cent. In our personal series of cases large open wounds caused a 25 per cent. mortality; closed wounds, a 7 per cent. mortality. The exceptionally low death-rate seen in statistics from base hospitals does not represent the true mortality in penetrating wounds. In how far complicating injuries to the spine and abdomen and multiple wounds have contributed to this mortality is not clearly evident from available statistics; yet we gather from the reports of nine authors who comment particularly upon the subject that they are responsible for or have largely contributed toward from 30 to 50 per cent. of the mortality in wounds of the chest.

Treatment of Penetrating Wounds of the Chest.—In the early stages of the war the treatment of penetrating wounds of the chest was conservative and expectant. The important features of this treatment consisted in absolute rest in bed, sufficient morphin to induce quiet, and measures to combat shock and other complications. The danger in early transportation of the wounded was recognized, but under the exigencies of war had often to be disregarded. This treatment sufficed for certain types of penetrating wounds, but was quite inadequate, as experience soon demonstrated, for certain other types. The realization of the necessity for active surgical therapy in the treatment of penetrating wounds came to surgeons of various countries at an indeterminate time. The expression of their views began to appear in the literature in the fall of 1915 and throughout the year 1916. It would require too many pages to trace the development of the surgery of penetrating wounds in the hands of the French, British, Italians, and Germans from the fall of 1915 to the close of the war. Two outstanding facts led to this development: (1) that over 60 per cent. of all cases dying at the front died within the first forty-eight hours from hemorrhage, shock, and open thorax; (2) that the later deaths occurred from infec-

tious complications. The attempt to lessen the immediate mortality and to prevent the later infectious complications led to the development of various surgical procedures and to the establishment of certain more or less fixed operative indications. As the war progressed and experience accumulated, penetrating wounds, from the standpoint of treatment, could be more or less clearly divided into two groups—those which required immediate surgical treatment at forward hospitals and those which could safely be treated expectantly. The former group eventually came to include the following: (*a*) those with primary hemorrhage threatening life; (*b*) those with open "sucking" pneumothorax; (*c*) those with large retained foreign bodies (over 1 cm. in diameter); (*d*) those with extensive rib-fractures ("stove-in" chest of British). The latter group included: (*a*) the perforating bullet and small shell wounds with small clean wounds of entrance and exit; (*b*) the penetrating bullet and small shell wounds with clean wound of entrance and without extensive rib fractures.

The latter group requires no discussion. For the benefit of those who have had no practical experience in war wounds a few words concerning the operative indications may be advisable.

(*a*) *Primary Hemorrhage Threatening Life.*—The term is self-explanatory. The condition has given rise to much discussion in the literature. Undoubtedly the vast majority of cases of serious primary hemorrhage died upon the battlefield or at the first-aid posts. Surgery did nothing for these, for surgical procedures were impracticable, especially in time of stress, at the first-aid posts. But there were a certain number which lived to reach evacuation hospitals or similar centers in which hemorrhage was the most urgent factor and in which timely operation could and did save lives. Duval[33] especially has insisted that primary hemorrhage constituted a real and urgent surgical indication, and among 161 cases reported from an evacuation hospital in 1918 he operated upon 16 cases for this condition. In a second paper[29] he collected 34 cases operated upon for primary hemorrhage, with 23 recoveries and 11 deaths. Hartmann,[51] certainly among French writers, has most strongly opposed the view that primary hemorrhage constitutes an operative indication, and from a study of the cases of Maisonnet, Grégoire, and Jeanbreau—a total of 534—concludes that, under existing war conditions, primary hemorrhage is never an indication for thoracotomy. Practically all patients, he finds, arrive at surgical centers in one of two conditions, either moribund from hemorrhage, shock or multiple wounds, in whom any operation is impossible, or with hemorrhage spontaneously checked, in whom operation for this condition is not indicated. It would be futile to comment at length upon the discussion of this question which has been carried on in the literature. There is no doubt in our mind that serious primary hemorrhage occurs, although very rarely, in cases which arrive at evacuation hospitals. It is seen in both closed and open wounds. In the former it is indicated by an increasing fluid level in the chest and, if severe, by pallor, sweating, air hunger, low blood-pressure, and rapid pulse. In

these cases it does not *necessarily* constitute an indication for thoracotomy, for the bleeding may spontaneously cease or aspiration followed by artificial pneumothorax may check the progressive hemothorax. In 110 cases of closed wounds of the chest in our series there were no deaths from primary hemorrhage and thoracotomy was never, in our opinion, indicated. There was one death from secondary hemorrhage from a torn internal mammary artery, the prevention of which might have been possible by thoracotomy had the recognition of the hemorrhage been more timely. In the open wounds of the chest primary hemorrhage is indicated by the continuous or intermittent escape of blood from the wound and from the general signs just enumerated. In these cases it is indeed difficult to determine whether the hemorrhage or the condition of open thorax is the more urgent factor in the production of shock, but in several instances we have found an active hemorrhage from a large wound of the lung, the continuation of which would certainly have influenced the prognosis. Our personal opinion is that primary hemorrhage is, although rarely, an urgent indication for thoracotomy, but that it should not be the cause of too hasty operative interference in the small open and the closed thoracic wounds.

(*b*) *Open "Sucking" Pneumothorax.*—Tuffier quotes Larrey[61] as having observed the remarkable results following occlusion of two open sucking wounds of the chest and as having stated that the ancients were accustomed to close these wounds even by suture. The necessity of immediately closing air-tightly open sucking chest wounds, first, to combat the immediate effects of open wounds, and second, to avoid infection of the pleura was perhaps the first principle in the operative treatment of thoracic wounds to be universally recognized and adopted. The only question in any doubt is the treatment of small open wounds (1 to 2 cm. in diameter). Many of these close spontaneously or can be closed by a pressure dressing. They should never be plugged with gauze to stop the opening, as was often done, but should be sutured if simple pressure does not effect a closure. The large majority heal without infection. The occasional infection of the soft part wounds with secondary infection of the pleura leads one to consider the advisability of excising them all and closing them by primary suture.

(*c*) *Large Retained Foreign Body.*—The term is ambiguous. It is meant to apply particularly to shell fragments, and includes, so far as I can gather, foreign bodies 1 cm. or more in diameter. That the retention of a large foreign body of itself constitutes an immediate operative indication is not universally conceded, but there are the following good reasons for so considering it: (1) Practically every large foreign body removed at operation is found capped by a mass of clothing or other débris. By analogy it would seem as important to remove this infected foreign body from the lung or pleural cavity as it is universally conceded to be from other tissues. The idea generally prevalent in the earlier part of the war that infected foreign bodies are well tolerated by the lung and pleura is still held by many, but considerable doubt of it has been expressed because of the frequency of infected

hemothorax, even in closed wounds of the chest, and by the accumulating numbers of late infections, hemoptyses, and pulmonary abscesses; (2) statistics indicate that the penetrating shell wounds with retained foreign bodies are the most fatal of thoracic injuries, not alone because of the extent of the primary injury, but because of the frequency of infectious complications; (3) available statistics show that perhaps 25 per cent. of all cases of hemothorax become infected, and most frequently those associated with large retained foreign bodies, and that as high as 80 per cent. of the deaths not occurring within the first forty-eight hours from hemorrhage, shock, and traumatopnea are due to these infections; (4) although statistics regarding the point are incomplete, they would seem to indicate that fewer postoperative infectious complications follow systematic removal of large foreign bodies than failure to remove them.

There remained to the end of the war two views as regards the large retained foreign body. Among the French, Tuffier and his supporters advocated the expectant treatment of closed wounds of the chest; the invariable and immediate closure of open wounds. The foreign body was more or less disregarded and became an important factor only when complications due to it arose. Duval and his adherents believed in the importance of the retained foreign body as the causative factor in infectious complications, and advocated its removal. Among the British there was at first rather a disregard, later a more definite tendency toward systematic removal, and in many of the contributions from 1917 on the large retained foreign body is included among the indications for operation. Among the Germans Sauerbruch emphasizes the importance of removing large infected foreign bodies. Our own view is that the large retained foreign body, plus the wound conditions which it causes, constitutes an operative indication. The wounds of the chest caused by the large foreign body present all the conditions which contribute to the seriousness of large wounds elsewhere. Even in the absence of an open sucking wound, more or less extensive rib or other fractures, large rents in the parietal pleura, in-driven infected fragments of bone, and laceration of the lung are the common rule—wound conditions which in the presence of an infected foreign body commonly, though not invariably, result in infectious complications. The so common occurrence of open pneumothorax in wounds caused by large shell fragments (75 per cent. in our series) makes this indication positive.

(*d*) *Extensive Rib Fractures.*—The experience of French, British, and German observers, which our own confirms, shows that extensive rib fractures in bullet, shrapnel, or shell wounds of the chest almost invariably result in pleural and pulmonary infections if left untreated, and that early operation is an efficient prophylactic against these complications. They are seen especially in the tangential wounds of the lateral, anterolateral, or posterolateral chest wall. One to four ribs may be extensively comminuted, producing a subcutaneous defect in the bony chest wall as large as 10 cm. in diameter.

Operative Treatment of Penetrating Wounds of the Chest.—Penetrating wounds presenting the operative indications discussed above formed perhaps less than 25 per cent. of all penetrating wounds of the chest. Duval,[32] an ardent advocate of the operative treatment of injuries of the chest, operated upon 28.5 per cent. of his cases, the remainder being treated expectantly. We who operated upon 25 per cent. of our cases felt from what we could learn of the experience of others in the A. E. F. that our proportion of operative cases was high. They were seen only at the forward hospitals, where alone the immediate treatment necessary for the preservation of life and the prevention of infectious complications was possible. The wounded arrived most commonly in our experience within twelve hours from the time of the receipt of their injuries and almost invariably in a condition of shock.

Frequently two questions arise before operation is undertaken: whether or not shock is so severe as to preclude immediate operation and, in the presence of multiple wounds, which wound should take precedence in treatment. In multiple injuries the wound of the chest, if open and sucking, takes precedence over injuries of the head, abdomen, and extremities unless they are actively bleeding, in which case two surgeons should operate simultaneously.

The question when to operate in shock is not so easily answered. In all thoracic injuries which present operative indications early operation is desirable; obviously, in continued primary hemorrhage; in open sucking wounds of the chest because recovery from shock and traumatopnea does not take place until the thoracic breach is closed; and in cases with large retained foreign bodies or extensive rib fractures in order to avoid infectious complications, operation should be done in the preseptic stage of the wound. Consequently, practically all operations in the past war were performed in the presence of some degree of shock, often in what we would have considered in civil life as serious shock. It is the experience of most observers, including ourselves, that thoracic operations are of themselves productive of little shock and may be performed without seriously affecting the patient's condition. Indeed, the condition of those with open wounds of the chest improves so soon as the thoracic breach is closed. But, notwithstanding the fact that operative procedures are surprisingly well borne, it is advisable in patients who are cold and severely shocked to institute preliminary treatment for shock either upon the operating table or in a "shock ward."

Treatment of Shock.—The subject has been considered elsewhere (*vide* Cannon's chapter on Shock in Vol. VII). Some remarks upon the treatment of shock in thoracic injuries, however, may be permissible. Absolute rest, external heat by hot-water bottles or, better, by heated beds; internal heat and gentle stimulation by hot drinks and coffee per rectum; and morphin in adequate doses to induce quiet have commonly a most marked effect in the moderate grades of shock. In the graver forms of shock in addition to the above measures elevation or bandaging of the

extremities, subcutaneous or intravenous infusions of saline, intravenous infusions of gum acacia, and blood transfusions (citrate method) may be tried. Stimulation by drugs is unsatisfactory. We personally know of no means of differentiating, at the time of admission, between shock the result of hemorrhage and shock without considerable bleeding, and consequently both groups of cases received the same treatment. As a rule the cases of shock due to hemorrhage (as proved by operation or autopsy) responded well to treatment and unquestionably most brilliantly to blood transfusion. Those in which hemorrhage was insignificant often failed completely to respond to any measures, including blood transfusion. Gum acacia (Bayliss's solution), so enthusiastically used by the British and recommended by the experimental division of the A. E. F., was a disappointment to us. It was given an extensive trial and its use was preceded and followed by careful pulse and blood-pressure observations. In the graver forms of shock, in which other than simple measures seemed advisable, it had no greater effect than intravenous saline; in grave and desperate shock it quite failed to influence the condition. This is not meant to imply that gum acacia is valueless in the treatment of shock. Cannon's experiments are quite convincing, but the conditions of his experiments, as we understand them, were the immediate treatment of recent shock. In the past war such conditions at evacuation hospitals never obtained. Shock, often profound, had existed for hours before treatment could be instituted. In our experience shock was the least satisfactorily solved of the problems relating to the treatment of penetrating wounds of the chest. Ten out of 160 thoracic wounds admitted in a condition of shock died immediately as a result of this condition, and the majority of the 25 per cent. of deaths following operation were due to the same cause.

Preparation of Patient.—Morphin and atropin are advisable and lessen the troublesome cough with bloody expectoration. Preliminary shock treatment may be begun just before or after the patient is on the operating table. If a transfusion of blood is given, enough blood should be obtained for a second transfusion at the completion of the operation. The position of the patient on the operating table must be governed to a certain extent by the position of the wound, but so far as possible it should be such as to avoid compression of the useful uninjured lung. The preparation of the skin needs little comment. Soap and warm water or, as is found very useful, hydrogen peroxid to remove the blood and dirt, and iodin or picric acid in alcohol, as used by the British as disinfectants of the skin, suffice.

Anesthesia.—Practical experience has given rise to the very general opinion that differential pressure anesthesia is unnecessary in operations upon the thorax. Among French and British authors this opinion is almost unanimous. In the A. E. F. the same opinion is held. Among the Germans, on the other hand, the opinion as expressed thus far in the literature is strongly to the effect that pressure anesthesia is necessary. Sauerbruch, Landois, Jehn, and others emphasize the difficulty of treating thoracic injuries because of the dangers of open pneumo-

thorax and advocate the use of simplified pressure apparatus at forward hospitals. A few (Landois and others) operated under simple chloroform or ether anesthesia, and without untoward results, but expressed regret that differential pressure apparatus was lacking. That it is unnecessary in the sense that war wounds of the chest can be satisfactorily operated upon without its use and with a minimum of risk from surgical pneumothorax must, we think, be accepted. In our own series, in which it was never used, there was not a single respiratory or cardiac accident nor could any of our postoperative deaths be attributed to this cause. That it is undesirable or that it should be discarded is not implied. In war practice we felt it might be useful to avert the cardiac and respiratory upsets that might occur, to test the adequacy of lung sutures and, perhaps, to obliterate the pneumothorax in closing the chest.

From a survey of the literature, various methods of anesthesia were employed, each of which claimed its adherents.

(1) **Local anesthesia** (novocain, novocain plus 0.25 per cent. potassium sulphate) has been recommended by French and British observers. A common method is paravertebral injections of novocain two or three spaces above and below the wound, with local injections about the wound. The most extensive operations are said to be possible with this method. Other authors comment upon the disturbance to the patient (cough, pain, restlessness) while the operator's hand is within the thorax, and therefore recommend nitrous oxid-oxygen anesthesia during this period of the operation.

(2) **General Anesthesia.**—Nitrous oxid-oxygen anesthesia had its supporters, who claimed that it caused the least shock and the fewest postoperative pulmonary complications. Ether anesthesia, because of its simplicity and its safety in the hands of untrained anesthetists, was perhaps most generally used. While many stated that ether and chloroform should never be used in operations upon the thorax, others were of the opinion that extensive thoracic operations should always be performed under general anesthesia and that ether was the anesthetic of choice. The frequency of diffuse pulmonary lesions (congestion, hemorrhagic consolidation) not only on the side injured, but on the opposite side, would appear to make the dangers of postoperative pulmonary complications considerable. In our own experience, however, they were surprisingly infrequent. Chloroform anesthesia was used by a few French and German observers, and with apparently satisfactory results.

(3) **Pressure Anesthesia.**—The great advantage of pressure anesthesia is that it prevents the cardiac and respiratory disturbances associated with open pneumothorax. In open sucking wounds of the chest it should improve the patient's condition and make him better able to withstand operation. It is a distinct disadvantage if used continuously during an operation, for experimental work and operative experience in injuries of the chest show that all operative procedures within the thorax can most easily and satisfactorily be carried out with the lung collapsed.

Our own experience does not permit us to comment upon the comparative value of these different forms of anesthesia. In our personal

series local anesthesia was satisfactorily used for the local excision and closure of thoracic wounds; it was found unsatisfactory in extensive procedures involving exploration of the chest with resection or suture of the lung. In these, general anesthesia with ether was used and with wholly satisfactory results. Other forms of anesthesia were not available.

Choice of Incision.—The choice of incision is dependent upon a number of factors. The excision of wounds being an essential step in the operation, the incision is made to include the wound if its position is such as to allow satisfactory exploration of the chest and treatment

FIG. 346.—PHOTOGRAPH SHOWING APPROACH IN A CASE OF PENETRATING SHELL WOUND OF THE BACK.

The smaller incision marks the wound of entrance. The resection of the apex of the lung and the removal of a large intrapulmonary foreign body were done after reflection of the scapula, procedures which might more easily have been done through an incision at a site of election in front. (Author's series.)

of the lesions within the thorax. In perforating wounds with wounds of entrance and exit far apart and at different levels the incision may be carried through the wound which best allows exploration of the thorax, the other wound being treated by local incision; or the local excision and closure of both wounds may be advisable and the exploration of the thorax conducted through a third incision made at a site of election. Duval[30] and many of his followers favor in the majority of cases an incision at the site of election, which extends from the midaxillary to the parasternal lines over the fifth rib and allows the most satisfactory exploration of the thorax. In the large open sucking chest wounds the incision is made to include the wound. In our own practice it was

possible in the large proportion of cases to conduct the operation through an incision which included the wound; and the incision has the advantage that it insures a satisfactory treatment of the wound of the chest wall, brings one most often immediately to the seat of trouble in the thorax, and avoids multiple incisions. It is unsatisfactory in wounds of the back which perforate the scapula and penetrate the chest. In one of our early cases of this kind resection of the apex of the lung and removal of a large foreign body were done from behind after reflection of the scapula (Fig. 346), procedures which could have been more satisfactorily carried out through an incision at a site of election in front.

Treatment of the Wound of the Thoracic Wall.—The wound in the skin is excised. Not so much viable skin should be removed as to prevent subsequent closure without too great tension; on the other hand, undermined and contused skin should be excised if there is any question of its viability in order to prevent subsequent necrosis and infection. All lacerated, contused, and infiltrated subcutaneous tissues are excised. The lacerated wound in the muscles overlying the ribs is excised and the excision carried outward around it until normal appearing, actively bleeding, and contractile tissue is encountered. Loose fragments of bone, if the wound involves the scapula or clavicle, are painstakingly removed and the margins of the fracture excised. The bony thorax is then exposed. The lacerated intercostal muscles and any loose fragments of rib are removed and the sharp ends of fractured ribs smoothed off with rongeurs. Hemorrhage from intercostal or internal mammary vessels is sought for and controlled. Throughout the foregoing steps too much wiping of the wound should be avoided. Infected bits of clothing and other débris should be sought for and picked out—not wiped about the wound with gauze. If the exploration of the thorax is not to be carried out through the wound, the wound is closed; if it is, the incision is continued from one or both ends of the wound, preferably after a change of instruments, gloves, and towels.

Opening the Thorax.—If exploration of the thorax is done through an incision at a site of election, an intercostal incision or an incision through the posterior periosteum of a single resected rib is preferable. Osteoplastic flaps should never, in our opinion, be used. If done through the wound of entrance or exit, 10 to 12 cm. of one of the fractured ribs is resected and the incision carried through its posterior periosteum. A rib-spreader of sufficient power is introduced and the thoracic cavity opened widely. Should a respiratory upset occur on opening the chest, the lung is quickly grasped and drawn into the wound and the wound about it temporarily closed with gauze.

Treatment of the Pleural Cavity.—This may immediately be proceeded with, or may better be left as a last step before closure of the thorax. The hemothorax is completely evacuated by siphonage or aspiration and the blood-clots and fibrin adhering to the visceral and parietal pleuræ and occupying the costodiaphragmatic sulcus are carefully removed with moist gauze. The hand is swept around the pleural cavity in a search for foreign bodies which so often lie free in the pleural

cavity. Irrigations of the pleural cavity with salt solution, mild antiseptics, or ether have been advocated and practised by some. Neither here nor in wounds elsewhere have we found it essential in obtaining satisfactory results. The presence of pleural adhesions (as in 3 of our cases) may delay operative procedures. Pneumolysis must be done before the lung can be satisfactorily treated, and is usually easy; but in one instance of our own—a combined thoracic and abdominal injury—the lung was so densely and extensively adherent in the costodiaphragmatic sulcus that resection of a considerable portion of the lower

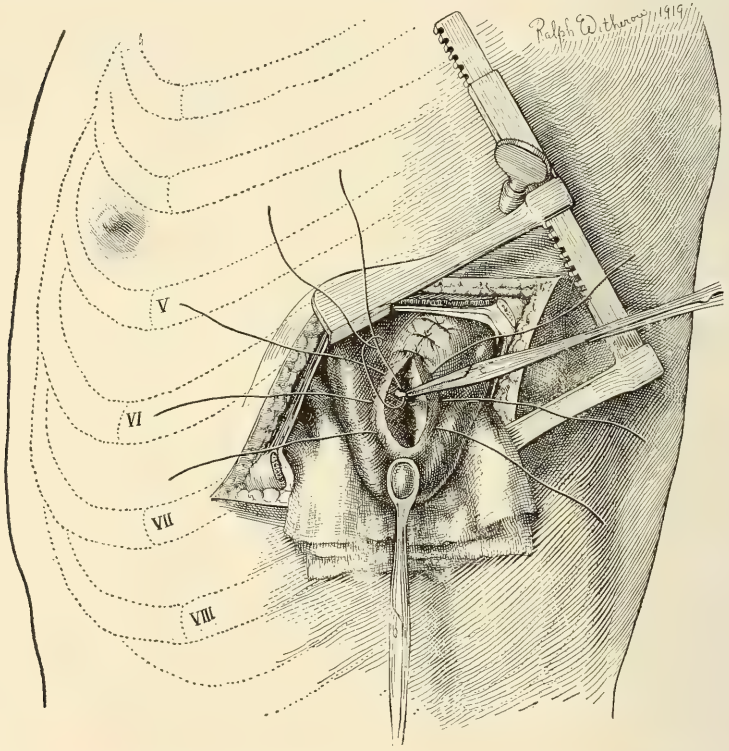


Fig. 347.—Treatment of a Simple Lung Wound.

The wound has been excised. A clamp is shown grasping one of the large pulmonary vessels. The deep sutures to control bleeding from the cut surfaces are shown; the pleural sutures are omitted. (Duval, "Les Plaies du Guerre du Poumon," Paris, 1917.)

lobe seemed the quickest and simplest way of exposing the diaphragmatic and hepatic wounds.

Treatment of Wounds of the Lung (Fig. 347).—The lobes of the lung may be delivered through the wound (exteriorization of the lung, Duval) if the necessary manipulations within the thorax are difficult. The common wounds of the lung requiring treatment are: (*a*) Shallow lacerated grooving wounds over the surface of one or more lobes; (*b*) perforating through the thin margins of one or two adjacent lobes; (*c*) shallow penetrating wounds with the foreign body embedded in the

lung; (*d*) deeply penetrating into the voluminous portion of the lung, with retained foreign body; (*e*) perforating through the voluminous portion of a lobe or through the entire lung, and (*f*) penetrating, with retained foreign body at the hilum or in the mediastinum. Granting that wounds of the lung should be treated as wounds elsewhere, the treatment of these wounds, aside from the control of hemorrhage, consists in the excision of the wound tract and the removal of all foreign bodies. In (*a*) the lacerated tissue forming the wall of the tract is excised with knife or scissors and any foreign bodies removed. Bleeding is temporarily controlled by grasping the lung on either side of the wound or by the application of non-crushing instruments of the stomach clamp variety. Individual large bleeding vessels may be caught with a clamp and tied. The oozing from the cut surface is controlled by a series of deep interrupted sutures. Careful suture of the visceral pleura completes the closure. In (*b*) the wound is either excised and sutured as just described, or, what is often a more satisfactory procedure, a triangular area of lung, including the wound, is resected and the cut surfaces approximated and sutured. In (*c*) the wound tract is laid open by section, the wound margins are excised, foreign bodies (including fragments of bone) are removed, hemorrhage is controlled, and the wound is sutured. In (*d*) and (*e*) a satisfactory treatment of the wound is rarely possible. Complete excision of the tract would involve large sections of the lung and division of large vessels and bronchi. Efforts at treating these wounds must be confined to local excision of the wounds of entrance and exit, cleansing the tract as well as possible, and removal of foreign bodies. These, if of any size, can usually be palpated through the lung and may be removed either through the tract or through a counterincision through the tissue of the lung. That such incomplete procedures are inadequate is illustrated by 2 cases—not our own—which died as the result of pulmonary abscesses developing around the unremoved fragments of bone. Whether or not the entrance and exit wounds should be closed by suture in wounds in which a large portion of the tract cannot be satisfactorily treated is, to us, an unsettled question. It is necessary in some instances to control hemorrhage from the wound; and it may prevent a secondary pleural infection. In (*f*) because of the large vessels in this region the removal of the foreign body should be done under the direct vision of the surgeon. If this is impossible, a second incision (the anterior incision of Duval—Fig. 347—or the incision shown in Figs. 352, 353) should be made; or the foreign body left in place to be removed, if indicated, at a later operation. In all operative procedures upon the lung the treatment of divided bronchi offers no difficulties. They are crushed, tied with silk or catgut, and covered with pulmonary tissue. But it should be remembered that we are dealing with small uninfected bronchi and normal pulmonary tissue, conditions quite different from those usually seen in civil life.

Closure of the Thoracic Wound.—Three methods of closure of wounds of the chest have been recommended and practised: (*a*) Closure

with drainage; (*b*) closure of the pleura and intercostal muscles, but without closure of the remainder of the wound, and (*c*) complete air-tight closure of the entire wound. The first method—used for a time by British, by a few French, and by German surgeons—because of the fear of infection proved highly undesirable. Drainage of an obviously infected pleura is self-evident. But operations were performed before obvious infection took place and largely with the purpose of avoiding infection. To drain the pleura under these conditions was to insure the infection which the operation was undertaken to avoid. Gray,[46] among the British, in 198 cases in which the pleura was drained had a mortality of 50 per cent.; among 57 cases in which the wound was completely closed, a mortality of 29.8 per cent. In the later stages of the war drainage was abandoned.

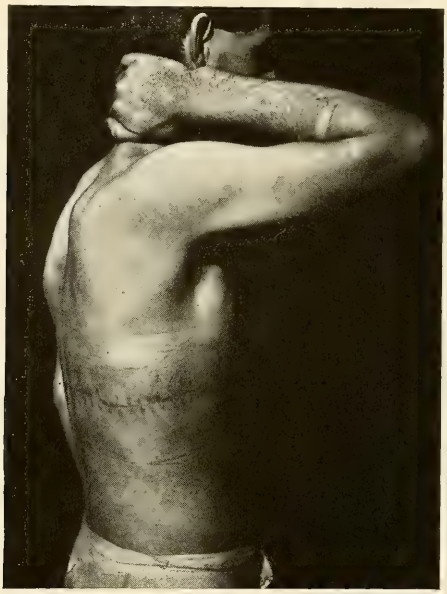


FIG. 348.—PHOTOGRAPH SHOWING A TYPICAL END-RESULT IN A CHEST WOUND ADEQUATELY TREATED. At operation three ribs were found extensively comminuted and were excised; a considerable area of lung was resected; a muscle plastic was necessary to close the thoracic defect. The wound was closed without drainage. The extent of the adhesive dressing may be seen. (Author's series.)

The second method also proved unsatisfactory, yet was used by many until the end of the war. The advisability of closing the pleura was recognized, but the wound of the soft parts was left open because of the fear of infection. The result, in a large percentage of cases, was infection of the wound of the soft parts followed by the reopening of the pleura with the development of a pyopneumothorax. We had at one time an admirable opportunity of comparing the results of this method with complete closure of the thorax. In my own cases, in which complete closure was invariably done, there was not an instance of pleural infection; in a group of cases operated upon by other surgeons with incomplete closure about 30 per cent. developed pyopneumothorax.

The complete air-tight closure of the thoracic wound is unquestionably the only proper method. Accurate approximation of the parietal pleura by a separate layer of sutures, as insisted upon by some, is considered unnecessary by others. In operations conducted through the wound it is usually impossible, due to laceration and loss of substance of the pleura. The intercostal muscles are accurately approximated by a series of interrupted sutures; but in large defects in the thoracic wall this also may be impossible. A muscle-plastic may be necessary to close the defect; or the lung may be sutured to the margins of the wound, a procedure never necessary in our experience. The overlying muscles are sutured in layers. The skin is completely closed (Fig. 348). A wide adhesive dressing supports the closure and lessens postoperative pain.

The operative pneumothorax may be treated by inflation of the lung at the moment the pleura is completely closed, or by simple aspiration of the chest at the completion of the operation. Depage, Duval, and perhaps a majority of surgeons favor removal of the air, stating that there are no contraindications if the lung has been carefully sutured, and that there is less postoperative respiratory distress. Others favor the spontaneous absorption of the air on the basis that the collapsed lung favors the control of bleeding and promotes healing. The removal of the air is not essential. Physical and *x*-ray examinations show that the air is completely absorbed in the course of ten days.

Postoperative Complications.—*Shock*, usually present before operation, may have to be energetically treated. Because of the nature of the injuries *pulmonary complications* may be expected in a certain, though small, proportion of cases. *Pleural effusions*—bloody, serous, or hemorrhagic—should be looked for and, if considerable, aspirated. Frequent cultures of the aspirated fluid should be made, for pleural infection is, in the experience of most, the commonest postoperative complication. Available statistics are not sufficiently detailed to form an accurate estimate of the frequency of this postoperative complication. Dobson[24] states that Gask and Wilkinson, in 67 thoracotomies with immediate closure, had 22 postoperative empyemas (32 per cent.); Anderson, in 58 thoracotomies with immediate closure, had 12 cases (20 per cent.); and Duval, in 29 thoracotomies with complete closure, had 9 cases (31 per cent.). In our personal cases of thoracotomy with immediate closure there were no postoperative pleural infections. Treatment, instituted early, consists in rib resection and drainage followed by sterilization of the pleural cavity with Dakin's solution. *Abscess of the lung* occurs, although rarely, in and about the wound tract and especially about foreign bodies. As noted in previous pages, it may arise early, within the first ten days, or later, after weeks or months. The acutely developing abscesses often result in septicemia and pyemia if untreated. Abscesses may be spontaneously evacuated into the pleura or through a fistula in cases with adherent lung, or may be expelled as a vomitus. *Postoperative hemorrhage* is rare. It should be treated as indicated under Hemothorax unless its severity requires re-

opening the wound. Serious hemoptyses have occurred in a few instances and may be treated by artificial pneumothorax. *Complications due to other injuries* may seriously effect the postoperative course and often are the cause of death.

Operative Results.—From the available literature, from 25 to 30 per cent. probably most accurately represents the operative mortality. This applies to the seriously wounded who, previous to operative interference, almost invariably died, and includes the mortality due to other injuries or their complications. The immediate operative results in the 75 per cent. which recover are excellent. In almost no other group of cases is restoration to normal so rapid and complete. The lung quickly expands to fill the pleural cavity and complete function of the lung is restored. There is less complaint of thoracic pain, dyspnea, and tachycardia on exertion than in the average untreated wound of the chest with hemothorax. We have no data which warrant statements regarding the late results.

DISTENTION OR PRESSURE PNEUMOTHORAX; MEDIASTINAL EMPHYSEMA

These two conditions, not discussed in preceding pages, require comment, although, so far as we can gather, little has been added to their diagnosis and treatment as a result of our war experience. They must have been very rare complications of injuries of the chest. By the majority of authors they are not mentioned, and in the entire series at an evacuation hospital we did not see an instance of either condition. Gatellier and Barbary[44] have seen 3 cases of mediastinal emphysema, one of which is especially reported by Hartmann. Phocas and Apert[83] have reported a case of the same condition. Sauerbruch states that both conditions are very rare and are usually seen together. *Pressure pneumothorax* due to valve-acting injuries of the bronchi or esophagus is indicated by a more or less rapidly progressing pneumothorax with dislocation of the mediastinal structures to the uninjured side and by the symptoms of dyspnea, cyanosis, and circulatory disturbances. It can occur only in closed wounds of the chest. Treatment is by pleurotomy or aspiration to relieve the urgent symptoms. Mediastinotomy or thoracotomy may be indicated if the lesion can be localized.

Mediastinal emphysema, the result of similar injuries, is indicated by the more or less sudden appearance of marked agitation and anxiety, tumefaction of the base of the neck, with a rapidly spreading general emphysema and signs of suffocation. The treatment has been considered in Keen's Surgery Volume VI, p. 398. In 2 of the 3 cases seen by Gatellier and Barbary lateral incisions under the clavicle did not satisfactorily permit the evacuation of the air, and both patients died. The third case, which recovered, was treated by a median incision at the base of the neck with separation of the pre- and peritracheal tissues. Phocas and Apert performed artificial pneumothorax, forcing air into the thorax—a procedure which was followed by a diminution in the dyspnea and emphysema and by eventual recovery. Mediastinotomy

or thoracotomy with closure of the lesion would seem the rational procedure. The difficulty lies in the localization of the fistula.

NON-OPERATIVE TREATMENT OF WOUNDS OF THE CHEST

The clean through-and-through bullet wounds, the penetrating bullet wounds without rib fractures, and the small clean-cut penetrating shell wounds with small retained foreign bodies do well under medical treatment and should be treated conservatively. Immediate treatment consists in absolute rest in a warmed bed in a position most comfortable for the patient, morphin to induce quiet, and measures to combat shock. The wound is iodinized and covered with a sterile dressing. Hemoptysis rarely requires treatment; may, if alarming, be treated by artificial pneumothorax. Subcutaneous emphysema is a complication of importance only in so far as it hinders physical examination. Subsequent treatment has been indicated in preceding pages. Compression symptoms are relieved by aspiration; hemothorax is treated as outlined under that heading; infectious complications in the wound, the pleura, or the lung on the injured or contralateral side are watched for and treated as they arise. Foreign bodies, in the opinion of the majority, should be left alone if not giving trouble; should be removed if responsible for complications. Absolute rest in bed for at least two weeks is desirable. Transportation of the wounded is inadvisable. Systematic respiratory gymnastics to hasten lung expansion and prevent retraction of the chest should be carried out.

GENERAL RESULTS IN THE TREATMENT OF PENETRATING WOUNDS OF THE CHEST

The immediate results in the treatment of penetrating wounds of the chest may be gathered from preceding pages. The mortality in the operative group is 25 per cent.; in the non-operative group, probably under 10 per cent. If we exclude the cases moribund on admission, in which treatment was impossible, our total mortality for both groups of cases is 13 per cent. This mortality includes that from early and later complications, for we had the fortunate opportunity of observing our patients over long periods of time.

The immediate and late symptomatic, functional, and physical results have been investigated by a number of authors. Briefly stated, the symptomatic abnormalities are indefinite thoracic pain, dyspnea, cough (either dry or accompanied by mucous or bloody expectoration), tachycardia, and intermittent attacks of fever with pulmonary signs. In varying number and degree they occur in from 30 to 80 per cent. of penetrating wounds of the chest not primarily operated upon, and persist for from weeks to two years. The functional disturbances are cardiac instability and diminished pulmonary capacity due to retraction of the chest and fixation of the diaphragm by adhesions.

The physical findings accompanying the above symptoms may be quite negative, but usually are retraction of the chest, with diminished

expansion, diminished excursion of the lower border of the lung, varying grades of pleural thickening, and fixation of the diaphragm in a high position. Rare sequelæ, as tuberculosis developing in the neighborhood of the wound and symptoms of hyperthyroidism, due supposedly to injury of the cervical sympathetic and vagus nerves, have been described. That the symptoms were overemphasized by many patients may well be believed; but that they often prevented an active life and a return to military duty is certain. There are but few statistics which show the percentage of injuries of the thorax returned to duty. Rudolf,[93] in reporting the disposal of 50 British wounded, found that 29 were returned to full duty, 4 to light duty, 3 to base duty, and 12 were permanently unfit for any duty. Thirty-six, or 72 per cent., therefore, were fit for some military duty; 14 cases were lost to the army. Elliott,[35] investigating the after-histories of 170 cases not primarily operated upon and invalided to England, found that in 95 cases of *sterile* hemothorax with and without retained foreign bodies, 59 were returned to duty after three months, 31 had a "fair" result, and 5 were totally unfit; in 64 cases of *infected* hemothorax with and without retained foreign bodies 29 were returned to duty, 15 had a "fair" result, 20 were totally unfit. French observers have reported that 50 per cent. of chest cases lead active lives and are fit for duty. Volkmann found among German wounded that 52 per cent. were able to return to active field duty, 40 per cent. were able to do garrison duty, and only 8 per cent. were unfit for any duty. In addition to the above sequelæ, reports of late complications (hemoptysis, pulmonary abscess, recurring attacks of septic bronchopneumonia) have been accumulating in the literature. These, together with the sequelæ discussed above, have by some been ascribed to processes resulting from the failure of the lung to tolerate foreign bodies, and have, therefore, brought up the question of the advisability of systematically removing foreign bodies from the lung.

LATE EXTRACTION OF FOREIGN BODIES

A minority of observers, Duval most strongly, advocate the systematic removal of foreign bodies because of the conviction that they are never perfectly tolerated by the lung, that they are responsible for the symptoms so commonly seen after thoracic injuries, and that they cause late complications. To these they add military and economic considerations. A majority of French observers, including Tuffier, Piéry, Petit de la Villéon, and Dénechau, and of British observers take a more conservative attitude and advocate their removal only when persistent symptoms or complications can definitely be ascribed to them. They do not admit that the common symptoms of thoracic pain, dyspnea, tachycardia, and cough are due to retained foreign bodies, but find that they frequently occur in their absence and that they persist after the removal of foreign bodies. Elliott found that in the *absence* of infected hemothorax men with retained foreign bodies are as quickly returned to duty as those without, and that there is no evidence to show that these men are subsequently crippled by them. After *infected*

hemothorax, however, 55 per cent. of the men with retained foreign bodies were unfit for duty after a period of six months, and only 20 per cent. without retained foreign bodies. Our personal experience does not permit us to express an opinion on the subject. From a review of the literature the following indications for the late extraction of foreign bodies perhaps best represents the views of the majority:

(1) **A Persistent Thoracic Fistula.**—Local treatment of the sinus tract may be tried. If ineffective, removal of the infected foreign body is indicated.

(2) **Late Hemoptysis.**—It occurs in two forms: a copious, sometimes dangerous, and often repeated hemorrhage; and very slight hemorrhages associated with persistent cough. The former is due to the erosion of a vessel by or to infection about a foreign body, and is a definite indication. The latter is associated with an unhealed pulmonary lesion about a foreign body and is a less definite indication unless persistent over a long period. Loeper, Verpy, and Cosnier[67] have attempted to differentiate between healed and unhealed pulmonary lesions by examination of the sputum. The presence of albumin and fibrin in a brownish or chocolate colored sputum indicates, in their opinion, an unhealed lesion, and is most often found associated with retained foreign bodies.

(3) **Late Abscess of the Lung.**—If evident, it is a definite indication. The difficulty in diagnosis has been commented upon. The unexpected finding of pulmonary abscesses about foreign bodies removed systematically and the expulsion of pus and foreign body in a vomica have been reasons for assuming the intolerance of the lung for foreign bodies.

(4) **Repeated Attacks of Bronchopneumonia.**—Recurring attacks of fever accompanied by cough and the physical signs of pneumonia are often seen after exertion and indicate infection of the lung about a foreign body. If persistent over a long period they are indications for removal of the foreign body. Piéry, as previously noted, insists that one to four attacks of this kind recurring over a period of two or three months are to be expected, and do not necessarily constitute an operative indication.

(5) **Symptoms of Thoracic Pain, Dyspnea, and Tachycardia.**—If unrelieved by gymnastic exercises and persistent over a long period (six months), and if disabling, removal of the foreign body is advisable.

(6) **The Size, Form, and Location of Foreign Bodies.**—These are relative, not positive, indications. Large foreign bodies are more likely to cause trouble than small; sharp and jagged projectiles are perhaps more likely to cause erosion of vessels and injury to pulmonary tissue than smooth; those near large vessels (hilum) may be more dangerous than those elsewhere. Removal of the foreign bodies may avert the accidents which might subsequently occur.

The **time of operation** is late, after the wounds are healed, and the primary symptoms following the injury have disappeared. The various operative procedures are as follows:

(1) **Technic of Duval.**[27]—After accurate localization of the foreign body with the compass of Hirtz, a large transpleural approach with resection of 10 or 12 cm. of a single rib is made in a position which will most satisfactorily expose the foreign body. The lung is exteriorized and the foreign body palpated and removed by the shortest route through an incision into the lung. The wound in the lung is sutured. The thoracic wound is closed without drainage. In the presence of old adhesions pneumolysis is necessary. The procedure is applicable in the extraction of foreign bodies in the pleura, lung, upon or in the diaphragm, and at the hilum. It may be satisfactorily used in the extraction of foreign bodies within the mediastinum and upon the pulmonary pedicle. It is inapplicable in cases with obvious infection (persistent fistulæ, pulmonary abscess). If after the thorax is opened the abscess is evident

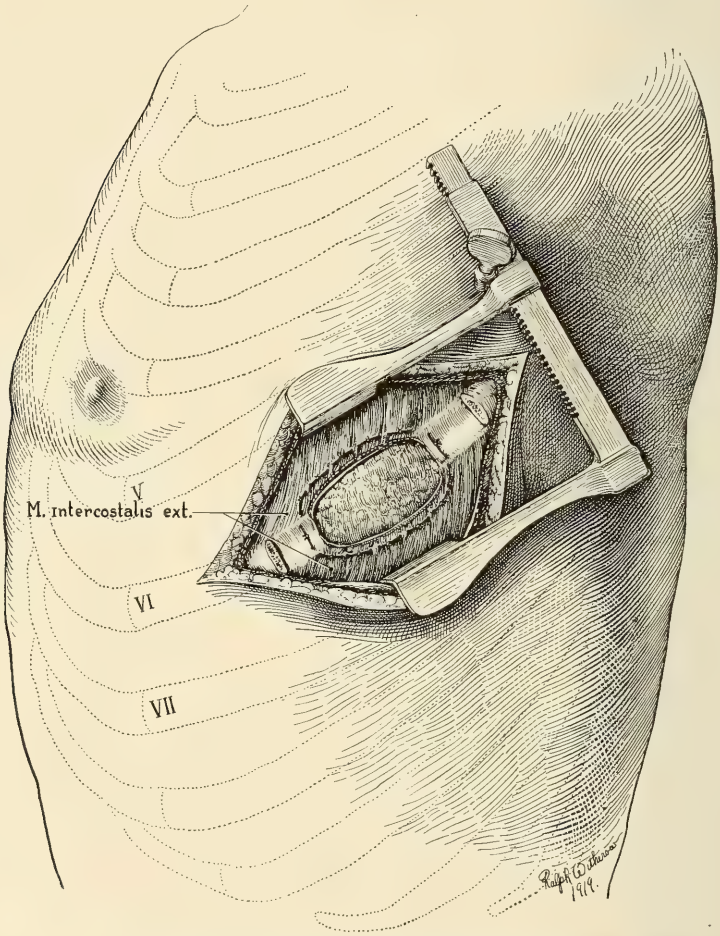


Fig. 349.—Marion's Technic for the Late Extraction of Foreign Bodies. The lung is shown sutured to the parietal pleura.

or suspected, the lung is sutured to the parietal pleura and the procedure converted into that of Marion. Its advantages are a large operative field, the possibility of removing foreign bodies by the shortest route and with the least trauma to the lung, the ability to control hemorrhage, its safety, and the absence of postoperative complications. The disadvantages claimed for it are that it is unnecessarily formidable and that there is danger of postoperative pleural infections; neither of which, judged from the results of the procedure, is serious.

(2) **Technic of Marion**[74] (Fig. 349).—Accurate localization of the foreign body. Resection of 4 to 5 cm. of a single rib. If the lung is not adherent, suture of the lung to the parietal pleura. Incision into the lung; introduction of the finger into the substance of the lung, disregarding the slight bleeding and escape of air; palpation of the foreign body; introduction of a clamp along the finger and removal of

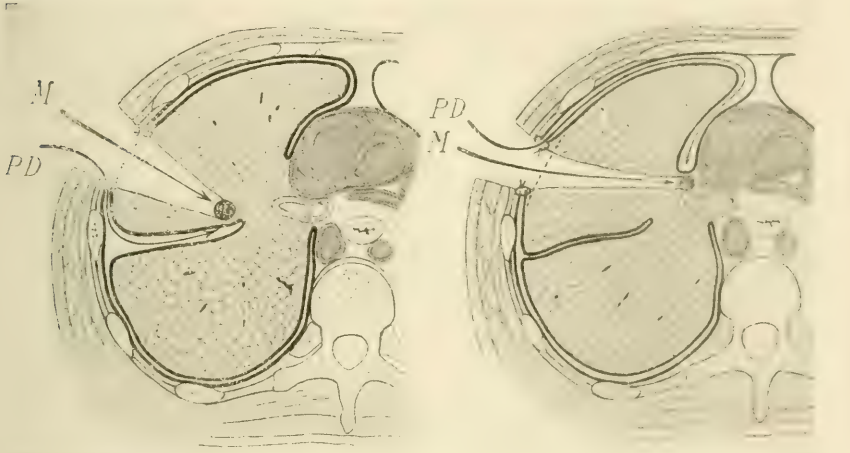


FIG. 350.—DIAGRAM OF DUVAL SHOWING THE DISADVANTAGES OF MARION'S TECHNIC IN THE EXTRACTION OF FOREIGN BODIES FROM THE LUNG AND THE ADVANTAGES OF EXTERIORIZATION OF THE LUNG. *M*, Marion's technic; *PD*, Duval's technic. (Duval, "Revue de Chir.," 1916, li, 375.)

the foreign body; tamponade of the wound. Removal of the pack in four or five days. In one paper Marion reports 27 cases operated upon by this method without operative mortality; in only one instance with failure to remove the foreign body. The procedure is especially applicable in cases with persistent fistulæ, in definite or suspected abscess of the lung, and in foreign bodies in the substance of the lung. It is inapplicable for the removal of foreign bodies in the pleura, in or upon the diaphragm, at the hilum, or in the mediastinum. Its advantages are the prevention of surgical pneumothorax and infection of the pleura. Its disadvantages are its limited application, its blind, rather brutal and often inconvenient approach to foreign bodies (Fig. 350), and its termination with drainage.

(3) **Technic of Mauclaire.**[75]—Through a small incision, with or without resection of a rib, a long suitable clamp is thrust directly through the pleura into the lung, and under the guidance of the fluoro-

scopic screen is directed to the foreign body. This is palpated, grasped, and withdrawn. The parietal wound, but not that in the lung, is sutured. The method has been slightly modified and extensively used and reported by Petit de la Villéon.[81] Through a mere buttonhole incision in the skin 7 mm. long, made under local anesthesia, a suitable clamp is thrust through the intercostal muscles into the lung and directed, with the aid of the fluoroscopic screen, toward the foreign body. The approach should be oblique in order to better direct the shadow of the clamp toward that of the foreign body. The foreign body is grasped by the clamp and withdrawn. The procedure is, with experience, very accurate, requires but a few minutes, and is safe. Petit de la Villéon has removed over 250 intrapulmonary projectiles by this method with, from a purely operative standpoint, remarkably good results. It is

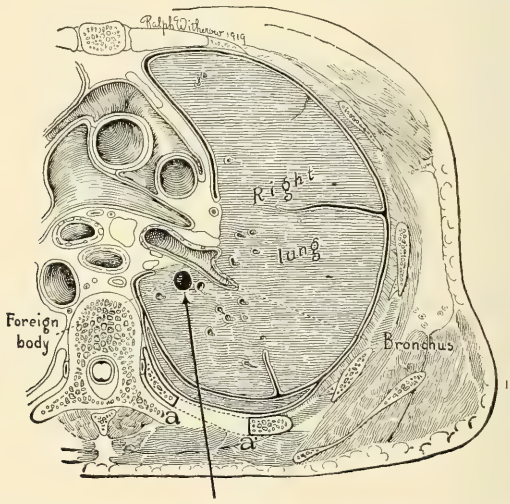


FIG. 351.—DIAGRAMMATIC REPRESENTATION OF PETIT DE LA VILLÉON'S AND DIDIER'S POSTERIOR APPROACH TO FOREIGN BODIES AT THE HILUM.

a–a', Operative defect in thoracic wall. The foreign body is removed with a clamp under the fluoroscopic screen. (Petit de la Villéon, "Presse med.," Paris, 1917, xxv, 259. Didier, R., "Presse med.," Paris, 1918, xxvi, 162.)

applicable in the removal of foreign bodies from the lung, the pleura, and the right side of the diaphragm. It is inapplicable, as Petit de la Villéon emphasizes, for the removal of foreign bodies at the hilum or in the mediastinum because of the danger of injuring the large vessels; or in or upon the left diaphragm because of the danger of injuring the underlying stomach and colon. It should not be used in the presence of obvious or suspected infection. Its advantages are its ease and simplicity in the hands of the experienced. Its disadvantages are the blindness and uncertainty of the approach in the hands of the inexperienced and the possibility of postoperative infectious complications. Mauclaire reports 5 cases of postoperative hemoptysis and pleural effusion, some of the latter requiring drainage.

Additional operative procedures have been described for the extrac-

tion of foreign bodies from the hilum, the mediastinum and pulmonary pedicle, and the medial and left sides of the diaphragm. The hilum, surgically speaking, intrapleural, and comprising the large vessels of the lung and the main bronchi, is admittedly one of the most dangerous regions of approach, and foreign bodies lying in front or behind it are the most difficult to extract.

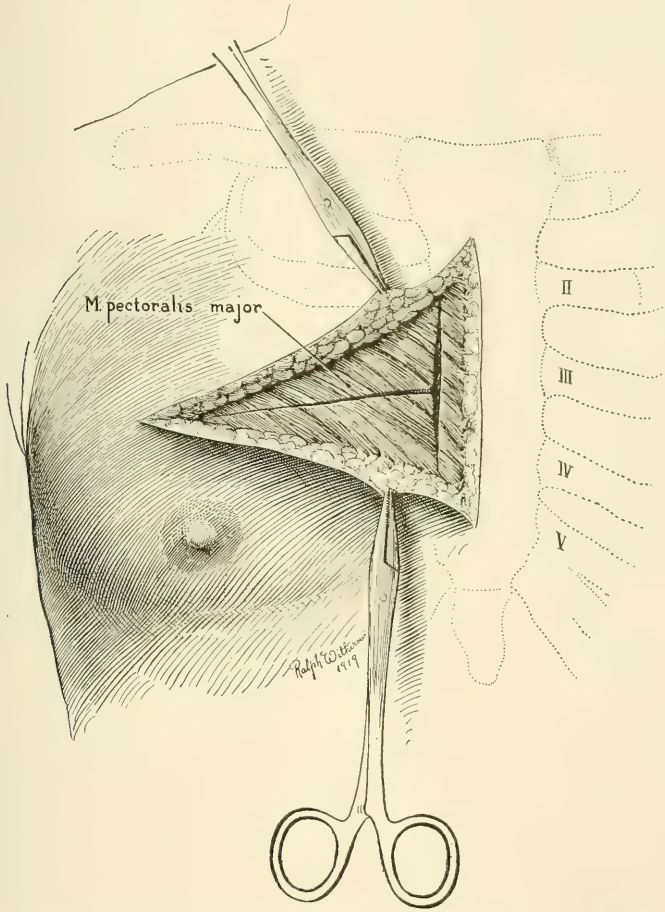


FIG. 352.—APPROACH TO FOREIGN BODIES IN THE MEDIASTINUM AND ABOUT THE HILUM. (After Tuffier and Le Fort.)

A posterior thoracotomy has been suggested and used by Petit de la Villéon[82] and Didier[22] (Fig. 351) in a number of cases, with satisfactory results. A rib (Villéon) or a costovertebral articulation (Didier) is resected between the scapula and spine and the foreign body removed with a clamp under the fluoroscopic screen. The wound is closed without drainage. The operative approach is limited, deep, and not without danger. The method of Duval, described above, or that of Tuffier and le Fort[63] (Figs. 352, 353) are apparently the methods of choice in

the removal of foreign bodies about the hilum. The same applies for those situated in the mediastinum and about the pulmonary pedicle (extrapleural), although some have recommended an approach through an osteoplastic flap, after the method of Delorme. For foreign bodies lying upon or embedded in the left half of the diaphragm Petit de la Villéon recommends a transpleural approach and extraction with a clamp under fluoroscopic guidance; for those medially situated a transabdominal approach through a median incision. Patel[80] suggests a low

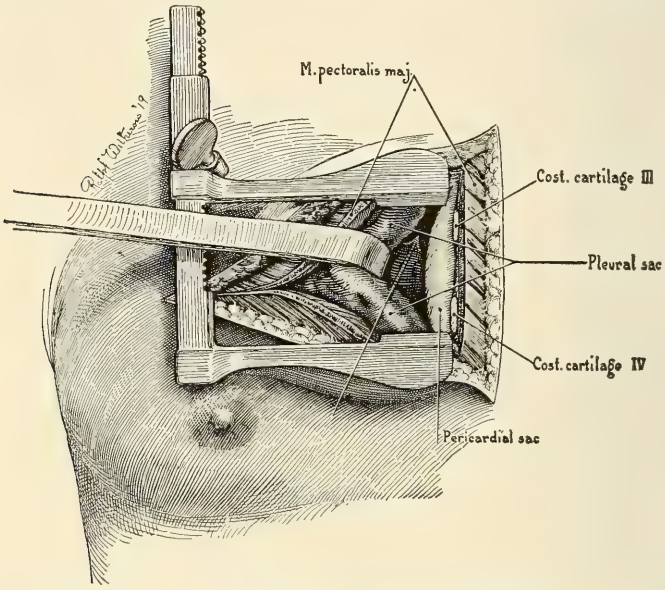


FIG. 353.—FURTHER APPROACH TO FOREIGN BODIES IN THE MEDIASTINUM AND ABOUT THE HILUM. The pleura is shown unopened.

thoracic and extrapleural approach for the removal of those situated in the anterolateral, lateral, and posterior regions of the diaphragm; a transpleural approach for those in its central region.

THE COMBINED INJURIES OF THE CHEST AND ABDOMEN

These include wounds which penetrate either the thoracic or abdominal wall, or both, perforate the diaphragm, and traverse in part both thoracic and abdominal cavities, injuring or not the thoracic and abdominal viscera. Although commonly seen at advanced hospitals, their frequency in the past war cannot be accurately stated, due to the fact that they were classified either under thoracic or abdominal injuries. At Evacuation Hospital No. 1 during a certain month among 1260 serious battle casualties surgically treated there were 105 pure thoracic wounds and 21 combined thoracic and abdominal wounds. They are among the most serious and fatal wounds which come to forward hospitals for treatment. Among the British, Rees and Hughes[88] had a 50 per cent. mortality; MacLaurin,[69] a 100 per cent. mortality.

Saint[95] in 16 cases treated surgically had only 3 deaths, but in none of the 13 cases which recovered was a hollow abdominal viscus injured. Among the French, Rouvillois, Pédeprade, Guillaume-Louis and Basset[92] had 50 serious injuries, 46 of which died; Grégoire and Courcoux,[47] 59 cases, 45 of which died. Baumgartner[4] in 13 cases treated surgically had 6 deaths. Among the Germans, Sauerbruch[98] reports 83 cases treated conservatively, with 72 deaths, and 14 treated surgically, with 4 deaths.

Varieties and Pathology of Wounds.—Grouped according to missiles, these wounds are either shell, bullet, shrapnel, or bayonet wounds. The first, certainly in our experience, was the most common. Shrapnel and bayonet wounds were rarely seen. The missiles either enter the thorax, penetrate the diaphragm, and lodge in or perforate the abdomen; or enter the abdomen and then penetrate the chest. The former was by far the commoner injury. The projectiles penetrated every part of the thorax and caused the greatest variety of wounds. Wounds in the vertical plane of the body were occasionally seen, the missile penetrating the supraclavicular space and lodging in the abdominal cavity. When the position of the diaphragm is remembered, all the lateral transverse, the medial anteroposterior transverse, and the downward oblique wounds which penetrate below the fifth rib are likely to be associated with injury to the diaphragm.

The commonest injury, in our experience, was the wound due to a shell fragment which penetrated the lateral wall of the thorax either upon the right or left side at the level of the seventh to the ninth ribs, perforated the diaphragm, and lodged in the liver or left abdominal cavity. The character of the injuries, too, is the most varied. The *thoracic wound*, depending upon the size and character of the missile, may be small, clean-cut, and "closed"; or large, lacerated, with comminuted rib fractures, and "open." Hemothorax of varying grade is almost invariably present. The *lung* in the very low wounds may escape injury, but usually the lower lobe is perforated or receives a gutter wound. The *diaphragm* may present a small punctured wound, often plugged (in left-sided injuries) by a bit of herniated omentum, or a large lacerated rent 10 cm. or more in length. It may be torn from its attachment to the wall of the chest over a wide area, the loose flap rising and falling with respiratory movements. Diaphragmatic hernias are common in the large diaphragmatic wounds and may present externally. We have seen the omentum protruding through the parietal wound at the level of the seventh rib. Duval[26] has reported a similar case in which the herniated omentum, attached to the wall of the chest, was at a late operation replaced into the abdomen. Stern[106] saw a fecal fistula in the seventh interspace which he closed, and then reduced the herniated small bowel into the abdominal cavity.

Most commonly, however, the diaphragmatic hernias are internal; of the right lobe of the liver in right-sided injuries, and of the omentum, stomach, spleen, transverse, and splenic flexures of the colon and small intestine in left-sided injuries. Bile and gastric and intestinal contents

may be discharged into the pleural cavity from the wounds in these organs. In a case of our own, gastric contents were expelled from a high thoracic wound with each act of vomiting.

The *abdominal viscera* may be very slightly or most seriously injured. Most remarkable are the cases of left-sided injury (including 3 of our own), in which, with an obvious wound of entrance, a proved perforation of the diaphragm, and the course of the missile such that injury to the abdominal viscera would seem certain, abdominal exploration either fails to reveal any lesion, or shows but a slight wound of the omentum. These, presumably, are the cases of combined thoracic and abdominal injury which recover without operation. Far more frequently, however, the abdominal viscera are injured; the liver, spleen, stomach, and the splenic flexure and transverse colon more commonly; the pancreas, kidney, and upper portion of the small bowel more rarely. The wounds of the solid organs vary from slight penetrating or gutter wounds to the most extensive lacerated wounds with fragmentation of the organs and excessive hemorrhage. Those of the hollow viscera vary from the small punctured wounds to large lacerated wounds with hemorrhage and the escape of gastric and intestinal contents.

Symptomatology, Clinical Signs, and Diagnosis.—Shock, often of the most profound degree, is the striking feature in these serious combined injuries; but may be quite absent in the small right-sided penetrating wounds and in the left-sided injuries without serious wounds of the abdominal viscera. All the symptoms of "closed" and "open" penetrating wounds of the chest are common to these injuries; and, in addition, they may have the symptoms common to abdominal injuries of abdominal pain, hiccup, and vomiting. The clinical symptoms are also those of closed and open thoracic wounds plus, in the majority of cases, abdominal tenderness and rigidity, chiefly over the upper half of the abdomen.

The *diagnosis* of these injuries is usually, but not always, easy. We may omit discussion of the cases with large open wounds of the chest through which the rent in the diaphragm can be seen; of those in which a *large* foreign body, by localization, is clearly within the abdominal cavity; of those with both thoracic and abdominal wounds, and of those with wounds of the abdomen, the flanks or the back, with clear evidence of thoracic injury. In these the diagnosis is quite obvious and the treatment clearly operative. In the small closed chest wounds, however, in which if an abdominal injury could be excluded expectant treatment would be indicated, the diagnosis of an associated abdominal lesion is more difficult. Abdominal pain, tenderness, and rigidity are commonly seen in pure thoracic injuries and do not necessarily indicate an intra-abdominal injury. Hiccup and vomiting are more rarely seen, but do occur in presumably pure wounds of the chest. Moreover, these symptoms may be quite absent in proved abdominal lesions. The localization of the foreign body is often of great help in the diagnosis and permits one to picture the course of the missile and the probable injuries to abdominal viscera. But, as above noted, the abdominal

viscera may escape injury when the foreign body has demonstrably penetrated the abdominal cavity. Moreover, the accurate localization of the foreign body may present difficulties, and the questions whether it has merely penetrated or has perforated the liver, or whether it is merely lodged in the diaphragm or has penetrated the stomach often arise. Diaphragmatic hernia may occasionally be diagnosed by physical signs and *x*-ray examination, but is extremely difficult of diagnosis in the presence of hemothorax.

Course and Prognosis.—In the early period of the war the treatment was expectant and resulted in a very high mortality. Patients died either early from hemorrhage, shock, open thorax, and abdominal injuries, or later from thoracic and abdominal infections. A certain number recovered, their clinical course interrupted by the development of subphrenic or hepatic abscess, localized abdominal abscess, or pleural infections. A comparatively few pursued an uninterrupted course to recovery. Experience would lead us to believe that these were the cases of right-sided injury with small retained foreign bodies in the liver, and the left-sided injuries without or with very slight abdominal lesions. In the later period of the war the need of immediate operative interference was recognized. The clinical course with operation improved, yet the mortality in the seriously wounded remained high.

The *prognosis*, then, depends upon the extent of the thoracic and abdominal injuries. In extensive wounds of the thorax associated with open pneumothorax and laceration of the lung, spleen, stomach, or bowel the hurt seems incompatible with life, and the large majority are either so shocked as to preclude operation or die immediately after operation. In the lesser injuries in which the thoracic wound is relatively insignificant and would be treated expectantly if pure, the prognosis depends largely upon the extent of the abdominal injuries. If hollow viscera are perforated, it is grave; if not, it is distinctly less so. The most favorable wounds are the simple penetrating wounds of the liver, the simple wounds of the spleen, and the left-sided wounds without injury to the abdominal viscera. With early operation the mortality for all groups is probably 50 per cent.

Treatment of Combined Thoracic and Abdominal Injuries.—This is almost entirely operative. In only two groups of cases may expectant treatment be applicable—in the small penetrating wounds of the chest on the left side, without demonstrable injury to the abdominal viscera, and in the small penetrating wounds of the right side, with small retained foreign bodies in the liver. In the former group the chances of error are too great, in our opinion, to warrant expectant treatment; but this attitude results, as in 3 of our cases, in the performance of unnecessary operations. In the latter group expectant treatment applies only to those with small retained foreign bodies and without evidence of excessive internal hemorrhage. At least 4 cases of this sort in our series recovered without operation or complications. Those with large foreign bodies are prone to develop infectious complications around the retained projectiles (abscess of the liver, subphrenic abscess).

In 11 wounds of the liver treated expectantly by Rees and Hughes,[88] 5 developed infectious complications. The transverse thoracic wounds which traverse the diaphragm and convex surface of the liver form a doubtful group. If small, with the small retained foreign body lodged in the thorax, they may be treated expectantly; if large, with a large retained foreign body, in our opinion operation is indicated because of the danger of infectious complications.

Operative Treatment.—The development of the surgical treatment of these injuries needs to be only briefly referred to. It took place concomitantly with, and as a result of, the experience gained in the treatment of thoracic and of abdominal injuries. The necessity of suturing the large wounds of the diaphragm was quite early recognized and at first was done by the abdominal route; later, because of its greater

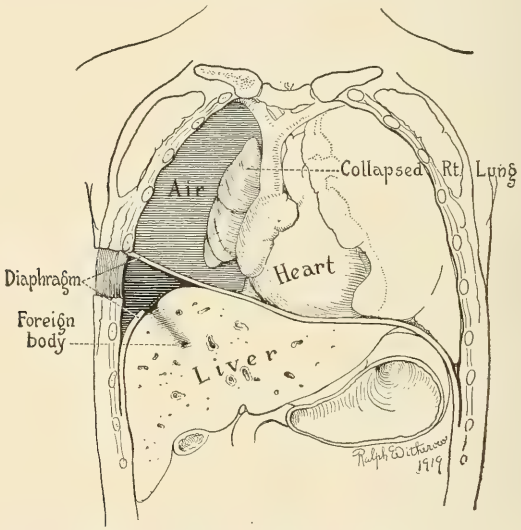


FIG. 354.—DIAGRAMMATIC REPRESENTATION OF THE SURGICAL APPROACH IN THE COMMON RIGHT-SIDED COMBINED CHEST AND ABDOMINAL INJURY.

The lung is collapsed; its wound sutured. The upper margin only of the diaphragmatic incision is shown sutured to the parietal pleura.

simplicity, by the thoracic route. The frequent necessity of treating thoracic wounds and the easy exposure of lesions of the upper abdomen through the diaphragm led to the general adoption of the thoracic approach as the primary step in the treatment of these injuries, to be followed by abdominal laparotomy only when abdominal lesions could not be reached by transthoracic laparotomy. The few exceptions to this operative course will be noted later.

Operative Technic.—The preliminary treatment of shock, the choice of anesthesia, and the position and preparation of the patient have been considered under Wounds of the Chest. To avoid confusion the operative steps in four groups of cases may be separately described:

(1) *Right-sided Penetrating Thoracic Wounds* (Fig. 354).—The incision is made at the level of, and includes, the wound. The same

careful excision of the parietal wound as described under the Operative Treatment of Penetrating Thoracic Wounds is done. The lower thoracic cavity is opened widely after resection of 10 to 12 cm. of a single rib. The lung is drawn into the wound, examined, and if injured is treated as described under Penetrating Thoracic Wounds. The wound in the diaphragm is excised. The diaphragm is split in the direction of its fibers so as to expose completely the wound of the liver. The margins of the diaphragmatic incision may or may not be sutured to the parietal pleura. This procedure has the advantage of closing the pleural cavity early in the operation, and *must* be done when drainage or tamponade of the liver wound is unavoidable. If it is done the hemothorax is first

FIG. 355.—PHOTOGRAPH OF A PATIENT WITH A RIGHT-SIDED COMBINED CHEST AND ABDOMINAL WOUND IN WHOM ACTIVE BLEEDING FROM THE LIVER AFTER REMOVAL OF A LARGE FOREIGN BODY COULD NOT BE CONTROLLED BY LIVER SUTURE ALONE.

The tampon was brought out through the thoracic wound. (Author's series.)

evacuated and the pleural cavity wiped dry with moist gauze. The hepatic wound is examined. In the shallow gutter wounds of the convex surface the ragged margins are excised and the wound closed with a series of deep interrupted sutures. The foreign body is removed through the operative wound if possible; if not, a counterincision over it is subsequently made. In penetrating wounds of the liver an instrument is inserted into the tract and the foreign body removed. The tract is cleaned as well as possible, the lacerated margins of the wound are excised, and the wound is closed by deeply placed sutures. Closure of the operative wound is either without or with drainage—always, if possible, the former. The diaphragm is tightly closed with interrupted sutures and the parietal wound air-tightly closed, as described for

penetrating wounds of the chest. If tamponade of the liver for bleeding or drainage for feared infection seems necessary, the tampon or drain is brought out either through the parietal wound (Fig. 355), or if this is not feasible, through a subdiaphragmatic stab wound. In the latter event the diaphragm and wall of the chest are completely closed.

Only rarely in our experience does the question of performing a secondary laparotomy arise. In the evident or questionably perforating wounds of the liver in which a large foreign body is not found thoracotomy should be followed by immediate laparotomy if the patient's condition permits it.

(2) *Left-sided Penetrating Thoracic Wounds* (Figs. 356–358).—For incision, treatment of the wounds of the parietal wall, and lung *vide*

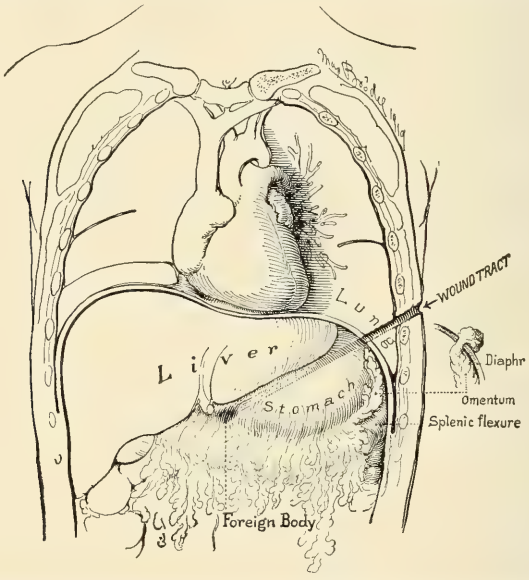


Fig. 356.—Diagrammatic Representation of a Common Left-sided Combined Chest and Abdominal Wound.

In the small sketch to the right the omentum is shown prolapsed through the diaphragmatic wound.

supra. The omentum, if prolapsed through the parietal wound, is excised. On opening the pleural cavity a bit of omentum is usually found plugging the small diaphragmatic wounds; but in the large wounds the spleen, stomach, and a part of the colon or loops of small intestine are commonly prolapsed into the thoracic cavity. The diaphragm is split by an incision parallel to its fibers. It may or may not be sutured to the parietal pleura, but perhaps should be to avoid further soiling of the pleural cavity in cases in which there has been an evident leakage of gastric and intestinal contents. Before it is done the pleural cavity is carefully cleansed. With the diaphragm held widely open a systematic examination of the upper abdominal viscera is made. The spleen, the greater and lesser curvatures of the stomach, a considerable portion of the left lobe of the liver, the splenic flexure, and the distal

half of the transverse colon are accessible for examination, and such procedures as splenectomy and hepatic and intestinal suture easily possible. After the discoverable visceral lesions have been treated the hand may be passed into the abdominal cavity in a search for injuries to the kidney, pancreas, and other organs. The exact location of the foreign body, determined before operation, will guide the direction and extent of this examination. The toilet of the peritoneal cavity is then

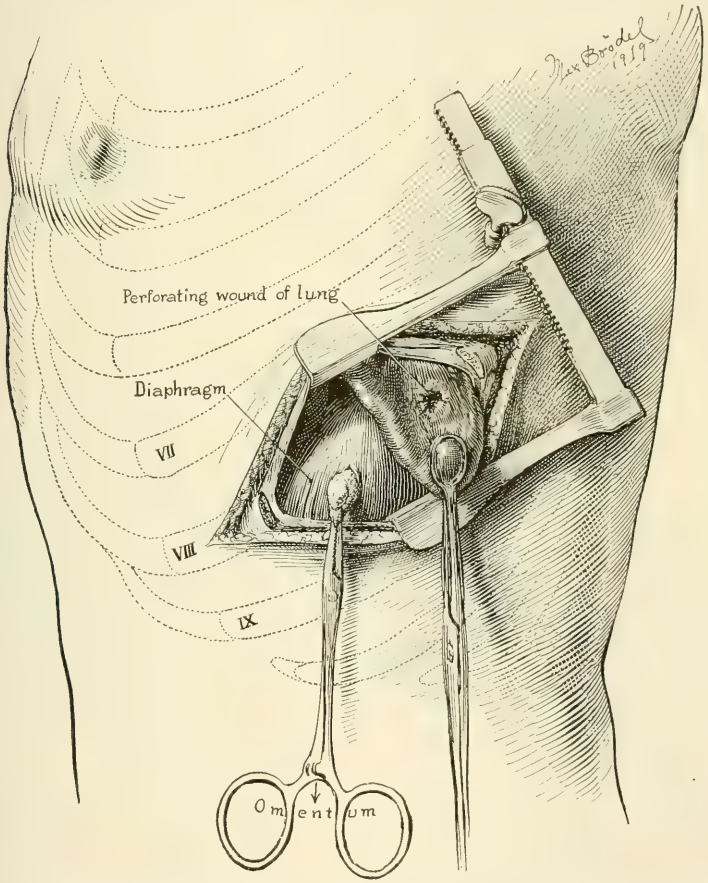


FIG. 357.—OPERATIVE APPROACH IN LEFT-SIDED COMBINED CHEST AND ABDOMINAL WOUNDS.
The lung is drawn into the wound showing the perforating wound of its lower border. The clamp is attached to the omentum which has herniated through the diaphragmatic wound.

made and the diaphragmatic and parietal wounds closed without drainage (Fig. 359). In our experience drainage accomplishes little and was not used even in the presence of evident soiling of the peritoneal cavity.

In a number of these cases doubt as to the advisability of an added and immediate abdominal laparotomy will arise; and little can be said to guide the surgeon in his conduct. In the absence of demonstrable leakage from hollow viscera experience shows that transdiaphragmatic

laparotomy alone suffices; in the presence of leakage which cannot be satisfactorily accounted for, in hemorrhage which cannot be controlled, and in wounds of organs which are not thus accessible, abdominal laparotomy is advisable. It may be carried out through a continuation of the thoracic incision (Fig. 360) or through a separate abdominal incision (Fig. 361).

(3) *Perforating Thoracic and Abdominal Wounds.*—Most commonly these are bullet wounds. The wound of entrance is in the thoracic

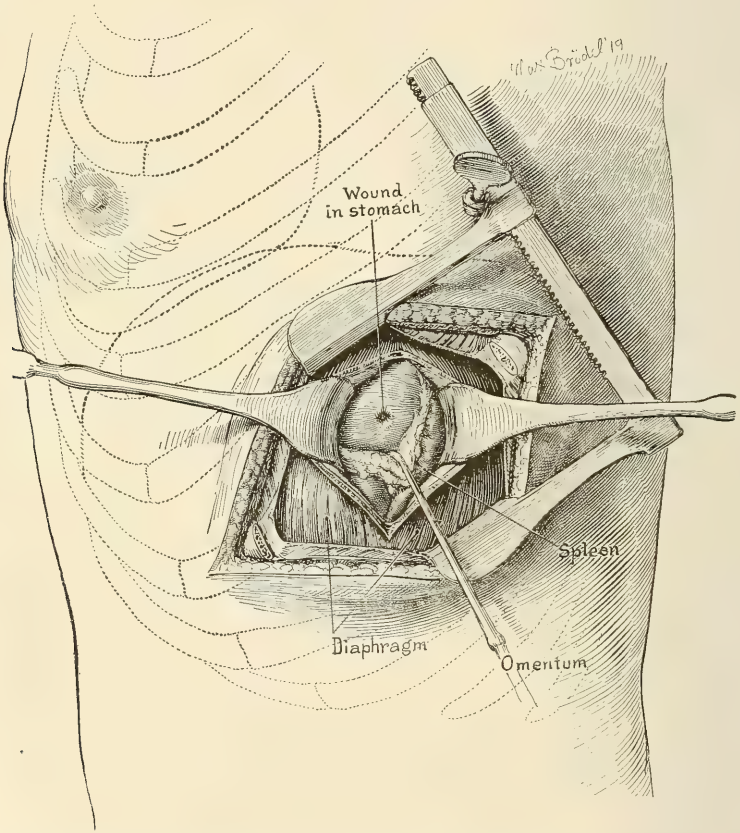


FIG. 358.—OPERATIVE APPROACH IN LEFT-SIDED COMBINED CHEST AND ABDOMINAL WOUNDS. SECOND STEP.

The diaphragm has been split in the direction of its fibers and is held apart with retractors. A wound in the stomach is shown.

wall, the wound of exit in the abdominal wall, or the reverse. The foreign body is not retained. Only the choice of approach need be considered. In the right-sided wounds of the diaphragm the primary approach depends upon the character of the wounds. If the thoracic wound is large, open, and "sucking," it takes precedence, and the primary operation, conducted through the thorax, is followed by abdominal laparotomy; if small and closed, abdominal laparotomy is first

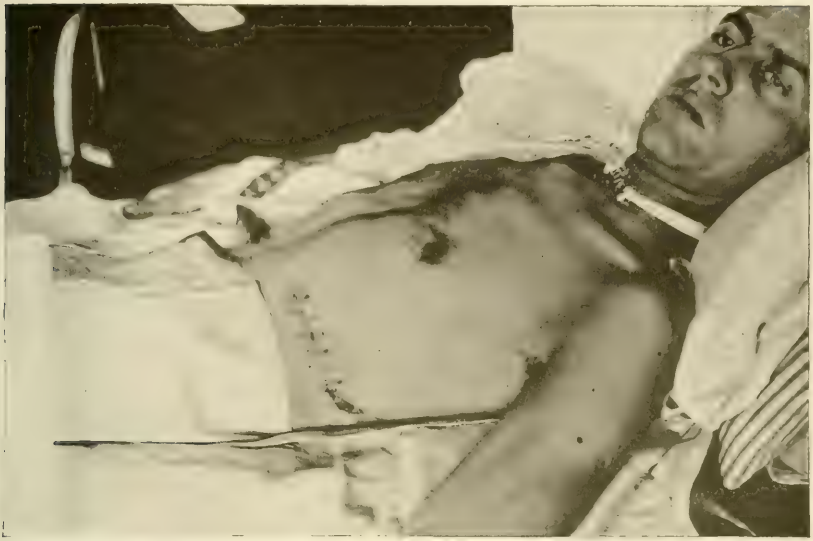


FIG. 359.—PHOTOGRAPH OF A PATIENT WITH A LEFT-SIDED COMBINED CHEST AND ABDOMINAL WOUND.

At operation a transdiaphragmatic splenectomy was done. The wound was closed without drainage. A separation of the skin margins at the posterior angle of the wound followed a slight skin infection. A perforating wound of the neck with division of the trachea necessitated tracheotomy. (Author's series.)

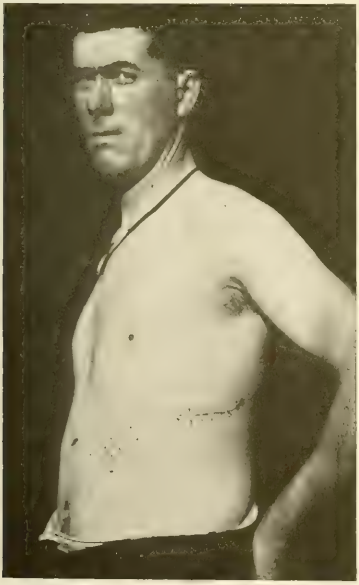


FIG. 360.—PHOTOGRAPH OF A PATIENT WITH A COMBINED CHEST AND ABDOMINAL INJURY SHOWING THE THORACIC INCISION CARRIED DOWNWARD UPON THE ABDOMEN IN ORDER TO ALLOW A BETTER ABDOMINAL EXPLORATION. (Author's series.)

FIG. 361.—PHOTOGRAPH OF A PATIENT WITH A COMBINED CHEST AND ABDOMINAL INJURY IN WHOM BOTH TRANSTHORACIC AND ABDOMINAL LAPAROTOMY WERE DEEMED NECESSARY. (Author's series.)

done, and is followed or not by thoracotomy, the decision depending upon the size of the diaphragmatic wound and the amount of hemor-

rhage into the thorax. In left-sided wounds of the diaphragm the same statements apply; but here, because of the frequency of diaphragmatic hernias, the difficulty of suturing the diaphragm from below and the danger of infection of the pleural cavity by escaped abdominal contents, thoracotomy is more often indicated.

(4) *Penetrating Abdominal Wounds.*—In these the wound of entrance is in the abdominal wall, flank or back; the projectile perforates the right or left diaphragm and lodges in the lung, the wall of the chest, or lies free in the pleural cavity. There is no external thoracic wound. In wounds by large shell fragments both thoracotomy and laparotomy are necessary, the primary procedure depending upon the seriousness of the thoracic and abdominal lesions. In wounds by small shell fragments the statements under (3) above apply.

Postoperative Complications.—These are most commonly of an infectious nature and include the complications considered under penetrating wounds of the chest plus peritonitis, localized abdominal, subphrenic, and hepatic abscess. Their diagnosis and treatment require no comments.

Operative Results.—Only a few statistical studies of the combined injuries of the chest and abdomen are as yet available. The literature at hand and our own experience would indicate that the operative mortality, especially in those with injury to hollow abdominal viscera, is very high; in the less serious injuries—including those of the solid abdominal viscera—comparatively low. MacLaurin[69] reports 14 serious cases with 12 deaths (85.7 per cent.); Baumgartner,[4] 13 cases with 6 deaths (46 per cent.). Rees and Hughes[88] report a 50 per cent. mortality following abdominal laparotomy, but we cannot gather whether or not the thoracic wounds were treated. Saint,[95] in 16 cases, had only 3 deaths (19 per cent.); but an examination of his cases shows that none of those which recovered had perforating wounds of the hollow viscera. Jehn,[58] in 14 cases, had 4 deaths (29 per cent.). It is probably the same series reported by Sauerbruch.[98] In 30 cases of which we have accurate records the mortality in the seriously wounded (open thorax, wounds of the lung, laceration of the diaphragm, stomach, and bowel) was 100 per cent.; in the less seriously wounded (liver, spleen, small wounds of the stomach or large intestines) was 40 per cent. The total mortality for all groups was 50 per cent. In the cases personally operated upon by myself the mortality in the former group was 100 per cent.; in the latter group all recovered. The total mortality was 46 per cent.

CIVIL THORACIC SURGERY

No attempt can be made to cover the subject; only such reference to new methods in the treatment of thoracic conditions or to results obtained by older methods as have not appeared in Volumes III and VI will be considered.

Pyothorax.—Reference may be made to Volumes III and VI for a general discussion of this subject. The epidemic of pneumonia which existed in practically all military camps during the early part of the

year 1918, and which was complicated by empyema in a high percentage of cases, gave a new impetus to the study of this condition. Excluding reference to the many interesting points brought out by the Empyema Commission, the outstanding facts for us are that in the vast majority of cases the empyema was due to the hemolytic streptococcus; that an effusion appeared very early in the disease when the patient was extremely ill with pneumonia; that this effusion was at first serofibrinous —only in from two to three weeks becoming frankly purulent; and that early operation was accompanied by a mortality of 30.2 per cent., which by late operation was reduced to 4.3 per cent. The explanation of this lowered mortality is that early operation carries with it the danger of collapse of the lung at a time when the patient, because of his pneumonia, already has too little breathing space. When done late, adhesions have formed, preventing collapse of the lung. The treatment instituted by the Empyema Commission was repeated aspiration until the fluid becomes frankly purulent, or until the patient's condition, from the standpoint of his pneumonia, is improved. Rib resection and drainage is then performed, with subsequent sterilization of the cavity. It has been a valuable contribution, in that in the treatment of empyema it has served to emphasize the importance of investigating the type of infecting organisms and of determining before operation the condition of both the affected and the opposite lung. But the mistake should not be made of applying this form of treatment to the postpneumonic pneumococcic emypemas commonly seen in civil life. It is interesting to note that delayed operation was practised by one group of surgeons in infected hemothorax; but in war wounds the opposite lung was usually sound and the danger of open pneumothorax minimal. The epidemic was productive also in an experimental way, and led Graham and Bell[45] to determine the relation of open pneumothorax to the treatment of empyema. The results of these experiments are at considerable variance with the hitherto prevalent views of the pathologic physiology of open pneumothorax. In brief, their conclusions are that the mediastinum in the human being is not an unyielding structure which may resist the atmospheric pressure of an open pneumothorax, but is so mobile that it offers no resistance to pressure on either side. For all practical purposes, from the standpoint of pressure relationships, the thorax may be considered as one cavity instead of two. The conclusion to be drawn from their paper is that the production of an acute surgical pneumothorax is a distinct danger in the treatment of empyema, as well as in other thoracic conditions.

Treatment of Pyothorax.—The primary treatment of empyema by rib resection and drainage, the various methods of inducing expansion of the lung, and the treatment of chronic empyema by various thoracoplastic procedures have all been considered by Dr. Brewer in other volumes of this work. He called attention in Volume VI to attempts which had been made to sterilize empyemic cavities by antiseptics (Murphy's formalin-glycerin solution, Beck's bismuth paste) and quoted some results which had been obtained by these methods.

It is in this direction that progress in the treatment of empyema, both acute and chronic, has been made. Surgeons previously directed their attention to the treatment of the cavity, and their efforts were directed toward its obliteration. Now their attention is rather directed toward the treatment of the infection, leaving the cavity to a certain extent to take care of itself. Our attention was called to this matter in 1913 by a case, unusual to us, in which we were able to sterilize a large, secondarily infected tuberculous cavity by the repeated injections of bismuth paste. The organisms, as determined by cultures and smears, progressively diminished, and a thick greenish pus was eventually converted into a clear serous fluid. The sinus tract spontaneously closed, leaving a large intrapleural cavity filled with sterile fluid. For months the patient remained well, not at all inconvenienced by the presence of this cavity. This observation suggested the possibility of treating empyemic cavities by antiseptic fluids, and various substances other than bismuth paste were tried. It led also to the thought that some of the small and favorably situated cavities of chronic empyema might be treated by immediate sterilization and closure. In 4 cases in which this method was used the wound in the chest wall was completely closed after the sterilization of the cavity with pure carbolic acid, and all healed *per primam.* The cavities remained for a variable time, but eventually were completely obliterated. With the discovery of the Carrel-Dakin treatment in the sterilization of wounds attention was directed toward sterilization of acute and chronic empyemic cavities by Dakin's solution; and favorable results were obtained in the empyemata of civil life. The large number of cases of infected hemothorax following penetrating wounds of the chest led surgeons to attempt this treatment in the infected war wounds of the thorax. Tuffier[111] and Depage[20] were leaders in this field, and the method was subsequently taken up by British and American surgeons. We can trace, therefore, a distinct tendency on the part of surgeons in the past few years to think more of the infection, less of the cavity; and the literature is beginning to contain reports of the results of this method of treatment. Tuffier[110] has reported 22 cases of chronic empyema, 7 of which were closed and healed at the time of the report, and 15 either closed for a short time or still under treatment; and 22 cases of acute empyema—12 medical cases and 10 infected hemothorax—in which sterilization was much less difficult and required a shorter period of time. Combier and Hertz[12] have reported 13 cases of infected hemothorax, with 12 successful results and one death following a simple thoracotomy. In the 12 cases which healed, 3 had to be reopened for a recurrence of the infection. The Empyema Commission[38] reported favorably upon this method of treatment.

Our personal series includes 15 cases of infected hemothorax, many cases of acute postpneumonic empyema which we have not yet had the opportunity of studying, and 24 of chronic empyema. In 11 cases of infected hemothorax which survived their primary wounds or the added infection the cavities were sterile and the sinuses closed at the time the

patients were discharged from the hospital. That these successful results were permanent we know in only 2 cases. In all of the 24 cases of chronic empyema treated either by the injections of Beck's bismuth paste, by irrigations with Dakin's solution, or by the immediate sterilization of the cavities with carbolic acid we know the end-results. There was no operative mortality. Twenty patients were discharged from the hospital with their wounds healed; 18 of these patients are well from seven months to four years; 1 patient died of pulmonary tuberculosis two years after his discharge from the hospital; in 1 patient (the only instance in the series of the reinfection of the cavity) a tuberculous focus subsequently ruptured into the cavity and death occurred following a second operation. Four patients were discharged from the hospital with their sinuses draining. Two of these patients are at present in tuberculosis sanitoria, 1 has died of pulmonary tuberculosis, and 1 has not been heard from. Our only failures thus far have been in patients with active pulmonary tuberculosis in whom a tuberculous empyema followed prolonged artificial pneumothorax treatment.

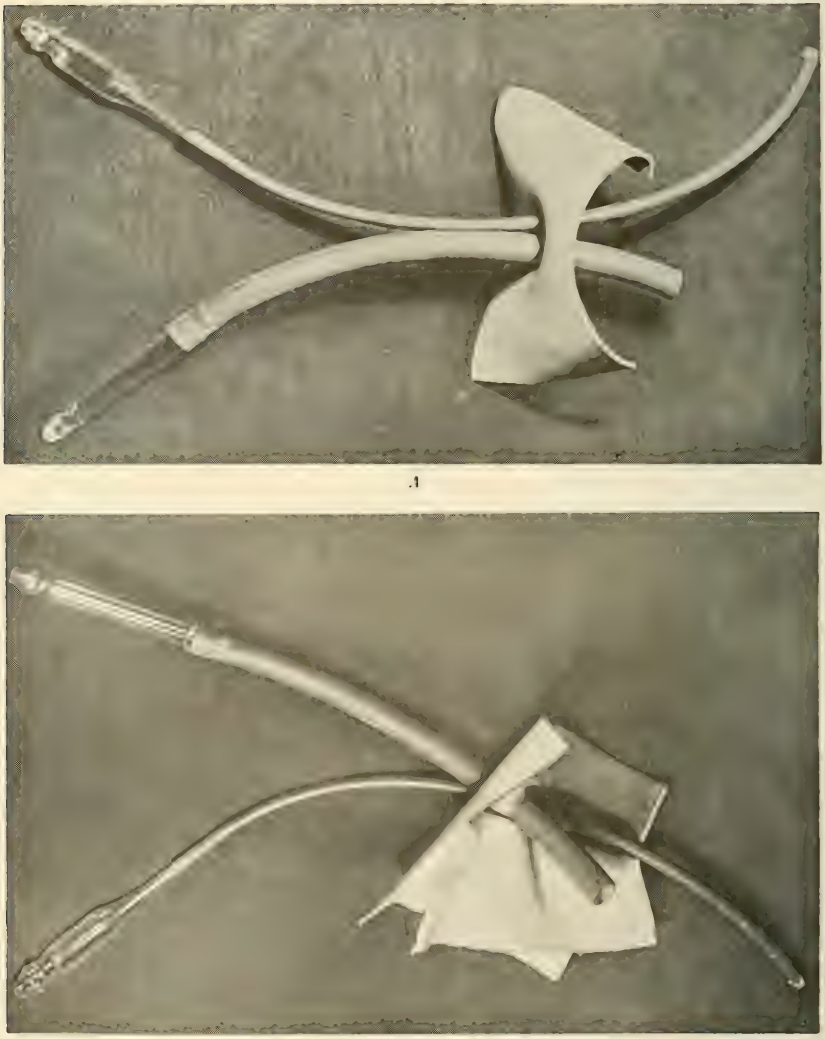
In the cases in which the sinus tracts were closed we know from *x*-ray studies that the cavities were not obliterated at the time of the closure of the sinuses; yet we know from later *x*-ray studies that eventually the cavities were completely obliterated, and by the expansion of the lung rather than by the retraction of the thorax. In the acute empyemata obliteration of the cavity may take place coincidently with its sterilization; in chronic empyema it may take place slowly, requiring, as in one of our cases, eight months.

Not less interesting than our observations upon the fate of the intrapleural cavities have been those upon the fate of the greatly thickened pleura surrounding the cavities. An examination of *x*-ray plates taken from a few months to a year after the sterilization and closure of the cavities shows that the thickened pleura entirely disappears and restoration to normal conditions is practically complete.

The complications which have been observed in the course of sterilization of empyemic cavities with Dakin's solution have been hemorrhage and the development of bronchial fistula. In the 11 cases of infected hemothorax neither complication occurred. In the 24 cases of chronic empyema hemorrhage from the cavity occurred in 3 cases, bronchial fistula developed in 2 cases. The hemorrhage was not excessive and ceased on discontinuing the irrigations. In 2 cases the irrigations were recommenced after the lapse of forty-eight hours and without a repetition of the bleeding; in 1 case irrigations were discontinued and bismuth paste injections substituted for them. Of the 2 cases in which bronchial fistulæ developed, 1 gave a history of previous fistula which had been closed for three months; the other was certain that the condition had not previously been present. In both cases the irrigations had to be discontinued because of paroxysms of coughing, the taste of the solution, and the fear of strangulation. Until the bronchial fistulæ had healed bismuth paste injections were substituted for the irrigations.

The steps in the technic of this method are as follows:

Acute Empyema.—(1) *Primary Rib Resection and Drainage.*—If the patient's condition warrants it, the opening of the chest should be sufficiently large to permit visual or instrumental inspection of the cav-



A

B

FIG. 362.—*A*, DETAIL OF THE TUBES.

The tube through which Dakin's solution enters the cavity is an ordinary Carrel tube. The large overflow tube just penetrates the thoracic wall. The cuff is of heavy rubber. It is attached to the thoracic wall by broad adhesive strips applied both to its outer and under surfaces. Those upon the under surface are folded (*B*) so that the folded margins come to the very edge of the wound.

ity. All adhesions causing the formation of pockets should be broken down, converting the cavity into a single space capable of being reached by the antiseptic fluid. Should the patient's condition be desperate, this procedure may have to be omitted.

(2) *Sterilization of the Cavity.*—At the time of the primary operation six to eight Carrel tubes are placed in all recesses of the cavity. Irrigations with warm Dakin's solution are begun on the day following operation, and should be done cautiously, avoiding a large amount of fluid, and ceasing at once if its introduction causes cough, dyspnea, or cya-

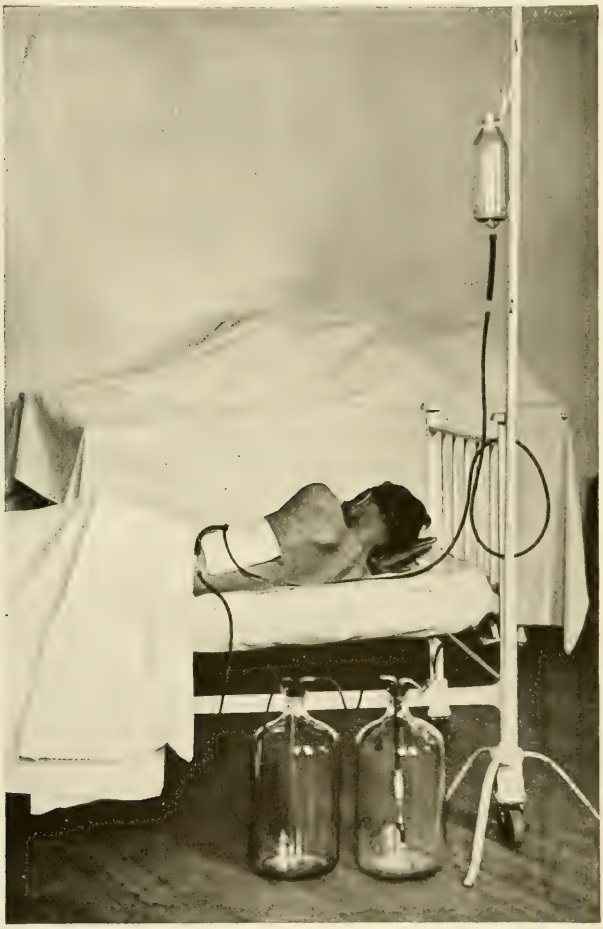


FIG. 363.—IRRIGATING APPARATUS FOR THE CARREL-DAKIN TREATMENT OF EMPYEMA CAVITIES.

The patient is placed so that the sinus is the highest point of the cavity. The cavity is filled every two hours, the patient being kept as long as possible in the posture indicated. The system of bottles upon the floor is the arrangement used by Hugh H. Young for bladder drainage, and is for the purpose of producing gentle suction upon the overflow tube during irrigation. In this way the overflow is promptly taken care of and the patient kept perfectly dry.

nosis. Gradually the pleura accustoms itself to the solution, which may then be introduced every two hours and in large amounts. Instead of the Carrel tubes we have used an irrigating apparatus which fills the cavity and permits the escape of the overflow through an outlet tube (Figs. 362, *A*, *B*; 363). It has the advantage that with a properly applied apparatus the patient is always dry. With the steril-

ization of the cavity the general symptoms improve. The temperature falls, signs of toxemia disappear, and the appetite returns. The discharge, at first copious and purulent, in the course of the first week decreases in amount and becomes clearer; then for a time is glairy and mucoid, and finally is perfectly clear. Periodic cultures and bacterial counts show in cases progressing normally a diminution in the number of organisms. Should the bacterial count remain stationary or show a rise, we may know that either the fluid is not reaching all parts of the cavity (due presumably to pockets), or that there is an infection of the parietal wound. The wound should then be explored, the pleural cavity inspected, and the necessary corrections made. The irrigations are then continued. The methods of obtaining cultures from the cavity are important; they may be made from different parts of the cavity with a long sterile glass pipet carefully introduced through the sinus tract, or by a small sterile catheter with a suction bulb, or from washings of the cavity withdrawn by suction from the dependent part of the cavity. Before closure of the sinus is contemplated two negative results should be obtained from cultures made after a period of from twelve to twenty-four hours without irrigation. It should be emphasized that here as in wounds elsewhere the treatment must be carefully and conscientiously carried out; otherwise favorable results will not be obtained.

(3) *Closure of the Sinus.*—The sinus tract may close spontaneously in from twenty-four to seventy-two hours after removal of the irrigating tubes. Perhaps a more certain way to avoid reinfection of the cavity from without is to excise the tract down to the parietal pleura and close the wound completely by secondary suture. This minor procedure can usually be done under local anesthesia.

Chronic Empyema.—(1) The size and position of the cavity with relation to the sinus is determined by *x*-ray examination after bismuth-in-oil or thorium injections. The cavity is opened widely by the resection of 8 to 10 cm. of one rib and inspected. Any adhesions causing the subdivision of the cavity into pockets are broken down or excised. The sluggish granulation tissue lining the cavity is wiped away or removed with a curet. The wound is closed save for an opening to accommodate the tubes. Steps (2) and (3) are carried out as described above.

Various combinations of procedures have been practised. Tuffier,[110] for example, has removed the thick and resistant visceral pleura after sterilization of the cavity. This, from the standpoint of the patient, is a simple operation as compared with the mutilating thoracoplastic procedures of Estlander, Schäde, Friedrich, Beck, and others. It is to be hoped that such operations will need to be resorted to less frequently as improvements in our treatment of acute empyema occur. Should they still be necessary in a certain number of the large cavities it is certain that they may more safely be carried out after sterilization of the cavity has been accomplished.

Pulmonary Emphysema.—The operative treatment of this condition advocated by Freund and described in Volume VI of this work

has been performed by many surgeons, and the following results of this treatment are at present available in the literature. Up to January, 1917 some 60 cases had been operated upon. The immediate effects of the procedure are an increase in the depth of the respiratory movements, a greater descent of the lower border of the lung on inspiration, and an increase in the vital capacity of the lung—in some instances of 100 per cent. The pulmonary and circulatory disturbances are improved. The permanency of these beneficial results has not yet been altogether established. Many of the 60 cases were operated upon by the old technic without the removal of the perichondrium; as a result the costal cartilages have re-formed and the condition has become re-established. A small number of cases have remained improved after three years. More recently (1918) Bircher and Freund[5] have reported the results of the treatment of 29 cases by this method. Six, or 19.8 per cent., had been cured over a period of from one to six years; 19, or 62.7 per cent., had been improved over a similar period; 4, or 13.3 per cent., were unimproved; 1 case died; 80 per cent. of the cases, therefore, have been improved by this method over a considerable period of time.

Surgical Treatment of Bronchiectasis.—The problems in connection with the treatment of this condition are not yet altogether solved. It is admitted that diffuse bilateral disease (only too common) and diffuse unilateral disease involving an entire lung are at present unsatisfactory for radical surgery. The former group of cases must still be treated by well-known though unsatisfactory general medical measures; the latter group has been treated by artificial pneumothorax, or by various thoracoplastic procedures, with almost equally unsatisfactory results. Bronchiectasis, however, involving a single lobe, and preferably the lower lobe (said by Robinson to occur in about 10 per cent. of the cases), has definitely come within the sphere of surgery. A review of the literature up to the present time giving the methods employed in the treatment of the disease and the results so far as known will give an idea of the present trend of surgery in the treatment of localized bronchiectasis.

A. **Incision and Drainage.**—This, the earliest form of surgical treatment, has now been employed in hundreds of cases. The early statistics showed a mortality of 62 per cent., with only 9 per cent. of cures. More recently Sauerbruch[99] has collected 123 cases of bronchiectasis treated by pneumotomy, with a mortality of 35 per cent., with 33 per cent. of cures and with little if any improvement in the remainder. Undoubtedly, the earlier poor results were due to a bad selection of cases. Only accurately localized saccular cavities could possibly be favorable for this method of treatment. There are in the literature fairly numerous isolated reports of cases of this kind cured by incision and drainage. The procedure at best has a very limited field of usefulness, and the trend of surgery has been away from incision and drainage as a surgical treatment of bronchiectasis.

B. **Collapse therapy** by rib resections was early applied in the

treatment of bronchiectasis. It was first suggested by Küster and Estlander in 1879 for the treatment of chronic empyemic cavities, later was used by Quincke in 1888 for the treatment of tuberculous cavities and other types of chronic tuberculosis, and more recently widely employed by Friedrich and Sauerbruch in the treatment of pulmonary tuberculosis. Various modifications of this method, such as the procedure of Tuffier, of Wilms, and others (see under *Surgical Treatment of Tuberculosis*), have been practised in the treatment of this disease. The literature contains isolated reports of improvement after these operations, but very few reports of cures. The consensus of opinion at present is that collapse therapy by the above methods is inadequate, rarely results in more than temporary improvement, and almost never may be expected to cure the condition. Many autopsy specimens show that while the more or less normal lung may be collapsed, the rigid walled cavities remain unaffected. The same may be said in general of collapse therapy by artificial pneumothorax. Even with an apparently total collapse of the lung the disease is but slightly affected. Moreover, in from 50 to 80 per cent. of the cases the treatment is inapplicable because of adhesions preventing the collapse of the lung. Collapse therapy, however, is not necessarily to be discarded. Better early diagnosis and more certain knowledge of when to operate and a better selection of cases may show some definite field for this procedure.

C. **Ligation of the Pulmonary Artery or of its Branches.**—Experimental ligation of the pulmonary artery has been carried out by Halsted[49] (1909), by Bruns and Sauerbruch[10] (1911), by Schumacher and Bruns,[101] and others. The eventual effects of ligation are shrinkage and fibrosis of the lung. Sauerbruch and others state that after a period of from six weeks to three months the lung may diminish in size to one-sixth of its normal volume. No untoward complications have followed the procedure. The effects of arterial ligations are, therefore, similar to those following collapse therapy, and the procedure has been suggested and tried in the treatment of bronchiectasis. Thus far the reports of the results are too few to form an opinion of its therapeutic value. It is possible that in the earlier stages of the disease this procedure may have a definite value. In the later stages it is not yet apparent that it may have more beneficial results than collapse therapy. Ligation of the pulmonary veins has been experimentally practised by Tiegel,[107] with the purpose of producing temporary congestion and eventual shrinkage and fibrosis of the lung. So far as I am aware, the procedure has not been applied to the human subject.

D. **Lobectomy or Resection of the Lung.**—The consensus of opinion at present among surgeons is that lobectomy or resection offers the best hope for the cure of bronchiectasis. The number of cases successfully treated by this method is steadily accumulating; yet it must be admitted that the mortality remains very high. Meyer[76] stated in 1914 that 16 cases of pneumectomy for bronchiectasis had been reported, of which 8 recovered, were cured or improved, and 8 died. He[77] reported a successful case in 1915, and Lilienthal[64] in 1916 reported 7 cases, with

4 cures and 3 deaths. Robinson[91] in 1917 reported 5 cases of complete resection of the lower lobe, with 1 death. In foreign literature there are a number of reports of successful lobectomy or pulmonary resection. Without going further into the citation of cases it may be said that resection of the lung and total excision of a lobe have apparently shown the highest percentage of cures, but are still fraught with great danger and attended by a high mortality. At the present stage of thoracic surgery cases for operation should include only those in a fair physical condition, with their disease confined to a single lobe.

The problems in the treatment of this condition by pneumectomy are those referable to the production of acute surgical pneumothorax, to the treatment of the bronchial stump, and to the control of infection. The various operative procedures to be described have been devised with the idea of solving them.

Operative Procedure.—A distinction must be made between resection of the lung and excision of a lobe. In the former sufficient presumably normal pulmonary tissue is available to cover the divided bronchi; in the latter the lobe is freed to a pedicle consisting of the bronchi and the main vessels. The former procedure is by far the safer, but is feasible in a relatively small proportion of cases. It would take too long to discuss the various methods of approach, the various ways of treating the bronchial stump, and the various methods of closure. Reference may be made to the appended literature. Briefly stated, the ideal procedure (simple thoracotomy, safe closure of the bronchial stump, and complete closure of the thorax), although attempted, has never, so far as we know, been successfully carried out in bronchiectasis in man; and the various procedures at present employed—often far from ideal—are designed to meet the complications of leakage from the bronchial stump, dislocation of the mediastinum with its attendant disturbances, and infection. The various steps in the procedures may be summarized as follows:

(*a*) *Type of Operation—One- or Two-stage.*—The choice depends on the condition of the patient. He may bear operation badly and it may have to be interrupted after the separation of adhesions and freeing of the involved lobe. Robinson[91] especially emphasizes the advisability of the two-stage operation.

(*b*) *Anesthesia.*—The majority of surgeons have found differential pressure anesthesia unnecessary, due to the presence of adhesions; a few have used it. Simple ether anesthesia seems adequate and satisfactory. Lilienthal employs intrapharyngeal anesthesia. For several days before the anesthetic is given postural treatment by Garvin's method is advisable for the purpose of completely emptying the bronchiectatic cavities.

(*c*) *Approach.*—Either by intercostal incision or by the resection of a single rib or by the resection of three to four ribs. The last method gives a wider exposure and subsequently obliterates in part the cavity which remains after the removal of the lobe. The almost invariable adhesions between the involved lung and the parietal pleura, diaphragm,

and adjacent lobes are carefully separated and the diseased lung freed down to a pedicle consisting of the bronchus and pulmonary vessels.

(*d*) *Treatment of the Bronchial Stump.*—The lung is either (1) resected or (2) amputated. (1) *Resection:* The pedicle is controlled by a clamp which includes bronchi and vessels. The lung is removed by an incision carried through the tissue of the lung. The individual bronchi and vessels are crushed and ligated. The lung is closed over the divided bronchi and vessels. An additional ligature may or may not be placed around the main bronchus (Tiegel). Resection has been less frequently done in practice than the following procedure. (2) *Amputation:* A crushing clamp is placed across the pedicle and the lung removed distal to it. A mass ligature has been the commonest form of treatment of the stump. Lilienthal, after crushing the pedicle, secures it with chain ligatures of strong chromacized catgut; and after removing the lobe carbolizes and ligates the bronchi and the individual vessels distal to the first ligature. Robinson uses the same technic, but in different order, and prefers kangaroo tendon or braided silk for the proximal ligature. Similar procedures are employed by Lenhartz and Sauerbruch. The sloughed stump is discharged after a period of days. The various methods of treatment of the bronchial stump (inversion, etc.) described and possible in experimental work have thus far been found inapplicable in bronchiectasis.

(*e*) *Closure.*—This, in recent literature, has always been with drainage or with gauze packs. Experience has convinced surgeons that at the present stage of the surgical treatment of bronchiectasis the dangers of leakage from the bronchial stump and infection are too great to warrant complete closure of the thorax. Drainage is with gauze or rubber tubes. Some form of drainage which prevents postoperative pneumothorax is preferable.

(*f*) *Avoidance of Surgical Pneumothorax.*—The to-and-fro dislocation of the mediastinum with its respiratory and circulatory disturbances is a complication to be feared. In the absence of adhesions between the remaining lung and the parietal pleura Lilienthal stabilizes the mediastinum by a ligature which transfixes the bronchial stump and is brought out through the parietal wound and fixed to the chest wall. Meyer advises differential pressure respiration for twelve to fifteen hours after operation. Robinson completely closes the thorax over a pack in the pleural cavity, subsequently opening the wound and gradually removing the gauze.

A discussion of these procedures would be of little profit at present. The whole problem largely centers about the closure of the bronchial stump. Could this be securely done, closure of the thorax would be possible, the fear of postoperative pneumothorax be removed, the frequent complication of bronchial fistula be avoided, and a prolonged convalescence be greatly shortened. The presence of a cavity within a closed thorax, if uninfected, is not, in our experience, to be feared.

The *postoperative complications* following the above operative procedures are the circulatory and respiratory disturbances noted, pneu-

monia, bronchial fistula, and empyema. Bronchial fistula is a common complication following the treatment of the bronchial stump as outlined above. In 12 cases in which its presence or absence is noted, it occurred 9 times. It may require subsequent operation for its closure. The pleura is invariably infected in drained cases and infection was the cause of the one death in Robinson's series; but how largely it has contributed to the mortality cannot at present be stated. It certainly affects the patient detrimentally and prolongs his convalescence.

Results.—Robinson's mortality in 5 cases was 20 per cent., Lilienthal's, in 7 cases was 42.8 per cent. Meyer found in 16 cases of pneumectomy collected from the literature in 1914 a mortality of 50 per cent. In 30 cases of resection or amputation of the lung (not all for bronchiectasis) reported by 14 surgeons the mortality was 20 per cent. The results of pneumectomy for bronchiectasis in those who recover from operation are perhaps still too indefinite to warrant any positive statements. In Meyer's collected series, 8 are reported as "cured" or improved; in his single reported case[77] paroxysms of coughing, but with very scanty expectoration, continued; Lorey's case is reported as cured. Robinson and Lilienthal's recovered cases are reported as cured or improved. Smith and Mudd[103] are doubtful as to the reported results. When analyzed closely they believe that only 2 of Lilienthal's cases and 1 of Robinson's are complete cures. We must wait for further data regarding this phase of the subject.

Dermoid Cysts.—In the literature the dermoid cysts, epidermoid tumors, and teratomata are usually considered together under the term "dermoid cysts," and we shall so consider them. The first two are practically always cystic tumors; the last is characteristically solid. Dermoid cysts arise in the mediastinum and vary in size from a walnut to a child's head. When small they lie in the mediastinum, when large they extend beyond it into the thoracic cavity. The genesis of these tumors need not be considered here. They are usually spheric, but may be flattened when in contact with the diaphragm. The cyst wall may be very thin or quite thick, and is invariably adherent to surrounding structures—the pleura, pericardium, great vessels, diaphragm, and thoracic wall—rarely to the trachea and esophagus. In it may be found pieces of bone and cartilage, and occasionally teeth; or it may be calcified in places. In carefully described specimens the inner lining of the cyst wall resembles skin. The contents of the cysts consists of desquamated epithelial cells, secretion of the sebaceous and sudoriferous glands, and fallen hairs. In one-third of the reported cases the cyst had perforated into the bronchus and therefore not only infection, but the presence of air has modified the character of the cyst contents. Malignant degeneration may occur in these tumors. In Dangschat's[14] 44 collected cases sarcomatous degeneration occurred in 3, carcinomatous in 1.

Symptomatology.—Symptoms may appear in childhood or may not be evident before adult age. Trauma or pressure on the thorax may

be given as the starting-point of the symptoms. These are thoracic pain—usually acute, sometimes dull and aching—which may radiate to the shoulder, to the back of the head, or down the arm; dyspnea—sometimes urgent—often noticed only on exertion, and cough with expectoration. The sputum in unruptured cysts may be small in amount and show nothing characteristic; in ruptured cysts it may be large in amount and foul. Hemoptysis is usually a late and not uncommon symptom. It is assigned as the cause of death in 5 of Morris'[78] 57 collected cases.

Diagnosis.—Physical and *x*-ray examination of the chest will serve to establish the presence of the tumor, but may not serve to differentiate the condition from other cystic tumors (echinococcus, etc.). In the cases in which rupture of the cyst into a bronchus has occurred *x*-ray examination with the patient in the erect posture will show the contents separated into two distinct layers by a horizontal line representing the fluid level. Examination of the sputum is of the greatest importance. As noted, in 33 per cent. of the reported cases rupture of the cyst into a bronchus occurred, and therefore sputum examination may be expected to aid in the diagnosis in many cases. The finding of epithelial cells resembling those of the horny layers of the skin, fat droplets, and cholesterin crystals is highly suggestive of dermoid cyst, but may occur in other conditions. The presence of hairs in the sputum is pathognomonic of this condition and occurred in 10 instances in Morris' series. Exploratory puncture has been done in a few instances, but is inadvisable.

Treatment.—Operative treatment offers the only hope of recovery. In 20 of Roger Morris' 57 collected cases operation was performed, and of these, 14, or 70 per cent., survived the operation and were either entirely cured or made satisfactory recoveries. In Dangschat's 44 collected cases 13 were operated upon, with 10 recoveries (77 per cent.). Operation has consisted in thoracotomy, evacuation of the cyst contents, partial excision of the cyst wall, suture of the remaining cyst to the thoracic wall (marsupialization), and cauterization and tamponade of its inner wall. Complete removal of the cyst—the ideal procedure—has rarely been feasible because of extensive adhesions to surrounding structure, and was possible in only one instance in Dangschat's series.

Surgical Treatment of Pulmonary Tuberculosis.—This subject has been discussed by Dr. Brewer in Volumes III and VI. A review of the various methods employed with the results at present obtained may be appended to his chapters.

(1) **Incision and Drainage of Tuberculous Cavities.**—This, the earliest form of treatment of tuberculosis and long since given up because of the uniformly poor results, has not been revived. De Forest[19] has more recently again summarized the results by this method of treatment.

(2) **Ligation of the Pulmonary Artery and Vein.**—This has been considered under Bronchiectasis. The cases of arterial ligation in the treatment of pulmonary tuberculosis are still too few to judge of the efficacy of the procedure.

(3) **Artificial Pneumothorax.**—This remains at the present time the

procedure of choice. The literature on the subject is enormous and thousands of cases have had the benefit of this treatment. A better selection of cases has improved the results and the former dangers of the operation (pleural reflex, gas embolism) have practically been eliminated. Sachs[94] has given the results obtained in 1145 cases reported by 24 American observers for the three years preceding his report: 88 per cent. were far advanced, 10.6 per cent. moderately advanced, and only 0.7 per cent. incipient cases of tuberculosis. Bilateral disease was present in 77 per cent., unilateral in 23 per cent. Cavities were present in 62 per cent.; tuberculous disease elsewhere demonstrable in 23 per cent. Evidently thus far the treatment has been applied chiefly in far advanced cases. The immediate results show 1.4 per cent. cured, 10.8 per cent. arrested, 9.5 per cent. apparently arrested, 29 per cent. improved, 18.3 per cent. unimproved, 16.2 per cent. dead; in 14.6 per cent. there was failure to produce compression; 6.2 per cent. of the patients were working. The method, therefore, resulted in improvement in 50 per cent. of the cases; failed to improve in an equal percentage. These immediate results are about the same, according to Sachs, as those obtained by European observers. The late results are not yet definitely known. The method is not applicable in from 20 to 50 per cent. of the cases. This is due to pleural adhesions which prevent collapse of the lung. Instead of the thoracoplastic procedures usually employed in this group of cases Torek[109] recommends separation of the adhesions by operation, closure of the chest, and subsequent pneumothorax treatment. Jessen[59] suggests extrapleural pneumothorax after stripping the parietal pleura from the wall of the chest. Neither procedure has been sufficiently tried to know its value.

As a result of accumulated reports the frequency of the postoperative complications of this method of treatment are better known. Of these, *pleural effusion* is the most frequent, occurring in more recent reports in from 30 to 50 per cent. of the cases. By the majority of authors it is thought to be the result of infection of the pleura by the tubercle bacillus, and to affect detrimentally the future course of the disease. It is prone to subsequent mixed infection. *Pyothorax* occurred in 13 out of 113 cases of effusion from American statistics. It is a serious complication and a difficult surgical problem. Rib resection with drainage, in our experience, eventually becomes necessary, and results in a persistent fistula communicating with an infected intrapleural cavity. Usually the patient's condition will not permit an extensive thoracoplastic operation to obliterate the cavity. Efforts should first be directed to the sterilization of the cavity as indicated under Empyema.

(4) **Thoracoplastic Operations.**—Jehn[57] has found that collapse of the wall of the chest by total rib resection has the same anatomic effects upon the lung as total artificial pneumothorax. Thoracoplastic operations, therefore, are applicable to those cases in which artificial pneumothorax is impossible because of pleural adhesions. Various methods of producing collapse of the wall of the chest and lung have been employed.

(*a*) *Friedrich's Extrapleural Thoracoplasty.*—This is the most extensive of the various procedures, and thus far has given the best results. Its author recommends that it be employed only in unilateral tuberculosis or in bilateral tuberculosis in which the disease on one side is quiescent. The operation is described in Volume VI of this work. The results have been very satsifactory and may be gathered from the report from the Zurich Clinic[54] (Sauerbruch, Henschen). Among 140 cases operated upon for tuberculosis, 31, or 22 per cent., were cured; 30, or 21 per cent., were considerably improved; 32, or 23 per cent., were improved; 4 were unimproved; 7, or 5 per cent. died as a result of the operation, and 31, or 22 per cent., died weeks, months, or years after operation from a continuance of their disease. By cure is meant freedom from all symptoms and ability to work over a period of from one to three years. These results are better than those obtained by artificial pneumothorax, but this undoubtedly is due to a better selection of cases. The mortality (5 per cent.), when the extent of the operation is considered, is surprisingly low.

(*b*) *Wilms' Extrapleural Rib Mobilization*[115] (Pfeiler Resection).—This procedure consists in the resection of short pieces (2 to 3 cm.) of the ribs at the costovertebral angle, combined with resection of short fragments of the costal cartilages. The portions of the ribs intervening between these two points are not removed. The wall of the chest sinks in and is held by a suitable compression bandage. The extent of the procedure depends upon the extent of the lesion, and may be confined to the apical region or applied to the entire thoracic wall. The resection of portions of the first rib—said by those with experience to be necessary—is the difficult part of the operation. It is less formidable than Friedrich's operation, but produces less collapse of the lung. The results, so far as published, are satisfactory, but few statistics are available. Wilms[116] reported 12 cases operated upon without a death, with satisfactory immediate results, but without comment upon the late results. Davies[16] reported 6 cases with no deaths, and with satisfactory immediate results. Maisel[71] reports 24 cases operated upon by this method between 1911 and 1912. The late results are: Healed for three years, 1; for two years, 3; for one and three-quarter years, 6; for one and one-half years, 5; for one year, 2; under one year, 2. Of the 24 cases he states that 4 are well; 9 greatly improved; 4 improved; 2 unimproved; 5 have died from their disease after variable intervals. The immediate mortality was nil.

(*c*) *Tuffier's Extrapleural Compression.*—The operation consists in stripping the parietal pleura from the wall of the chest over the seat of the disease and producing compression of the lung by the insertion of fat (omentum, lipoma) into the space between the parietal pleura and wall of the chest. The wound is closed without drainage. The procedure is chiefly designed to produce local compression (over an apex or cavity); is hardly applicable for compressing the entire lung. In the experience of Tuffier, Sauerbruch, Wilms, and others the free transplant heals in kindly and produces a lasting compression. Baer, em-

ploying the same method, uses paraffin for the filling material. The disadvantages of this over free transplants are that it is prone to become infected, and is either discharged or must be removed; that it may rupture into the lung or into a cavity, and that it wanders from its original position. The results of Tuffier's procedure and its modifications are at present indefinite. The experience of Tuffier, Sauerbruch, Wilms, and others who have employed it in at least 45 cases is that it does accomplish a *local* compression, the effects of which are the same as those in artificial pneumothorax and the larger thoracoplastic procedures. As a treatment for unilateral tuberculosis, however, it is inadequate. Sauerbruch, Wilms, and others have emphasized the fact that local compression is not sufficient even in disease confined to an apex or in presumably localized cavernous tuberculosis, but that compression of the entire lung is necessary. The procedure, therefore, finds its greatest usefulness in combination with the other larger operations—local compression of the apex combined with Friedrich's or Wilm's thoracoplasty over the remainder of the lung; local compression of a rigid walled cavity not collapsed by thoracoplasty, and so on.

(*d*) *Freund's Operation for Apical Tuberculosis*[40] (Paravertebral Decompressive Resection of First Rib, Henschen[53]).—The operation consists, as Freund described it, in division of the ossified costal cartilage of the first rib and the insertion between the divided ends of a piece of muscle so as to produce a false joint. Henschen, after an examination of autopsy specimens, concluded that parasternal division of the first costal cartilage did not have the desired effect of widening the thoracic aperture, and recommended resection of the paravertebral segment of the first rib. The operation is based upon the observations of Freund that in many cases of apical tuberculosis there is ossification and shortening of the first costal cartilage, resulting in stenosis of the thoracic aperture. The stenosis, often indicated by the furrow of Schmorl, causes compression of the apex, diminution in its aëration, and slowing of its lymphatic and blood circulation—factors which predispose to apical tuberculosis. In cases with spontaneous fracture of the ossified cartilage resulting in the development of a false joint he believed he found evidence of healing of the focus. His ideas have been tested experimentally. Bacmeister[1] and Hart and Harrass[50] support them; Sato,[96] Davies,[15] and Iwasaki[56] are at complete variance with them. It would appear at present that Freund's premises are incorrect and his operation valueless. In the early cases of apical tuberculosis it is doubtful that it has accomplished more than the usual medical treatment; in the more advanced cases it has proved inadequate.

(5) **Phrenicotomy** (Stuertz).—The procedure consists in division of the phrenic nerve in the neck, and was first proposed by Stuertz in the treatment of chronic infections of the lower lobe. Its effects, as proved by experimental, clinical, and *x*-ray investigations, are paralysis of the diaphragm, elevation of this structure to the position assumed in maximum expiration, diminution in size of the lower thoracic cavity, and limitation of the inspiratory activity of the lung (Carl,[11] Walther,[113] Sauer-

bruch.[97] The lung is, therefore, partially put at rest and its lower lobe mildly compressed. In experimental animals infected with tuberculosis the lung on the side in which the nerve is divided shows less disease than the other (Carl[11]). Walther[113] reports 26 cases, chiefly of tuberculosis, treated by phrenicotomy. The results indicate that the procedure produces rest and compression of the lung. As a treatment of unilateral tuberculosis it is inadequate, and for the same reasons as stated under Tuffier's operation. It is best used as an adjunct to other larger procedures. Sauerbruch[97] finds its chief usefulness in circumscribed disease of the upper lobe in which the thoracoplasty of Friedrich over this region is combined with phrenicotomy.

(6) **Pneumectomy; Resection of the Lung.**—These surgically feasible procedures have gained little favor in the treatment of tuberculosis. Lawson, Doyen, and Tuffier have successfully resected the apex of the lung, and Macewen has excised the entire left lung for advanced cavernous tuberculosis with a complete cure for sixteen years. Since the publication of Volume VI there have been no noteworthy contributions to this phase of the subject.

Differential Pressure Anesthesia in Thoracic Surgery.—The subject has been fully discussed in Volume VI, and is referred to again merely to point out the effect surgical experience in the past war has had on the previous ideas regarding the necessity of differential pressure anesthesia in operations upon the thorax. A survey of the literature on war wounds of the chest will convince the reader that in the minds of a great many surgeons the dangers of acute surgical pneumothorax had been overestimated, and that they have found that operations contemplating the opening of one thoracic cavity may unhesitatingly be done with a minimum of risk without the aid of differential pressure anesthesia. The rare circulatory and respiratory upsets which may occur on opening the thorax can be readily controlled by simple procedures. The recent experiments of Graham and Bell need not be assumed to contradict these statements. Regardless of the pressure relationships within the thorax and the degree of compression of the lung on the unopened side, clinical experience showed that respiration was sufficient for the needs of the patient during the period of operation. That open pneumothorax as seen in open sucking wounds of the chest affects detrimentally the patient's condition was abundantly proved, and the striking beneficial effects of closing these wounds have been universally recognized. It should be said, however, that in these, open thorax was associated with hemorrhage and other serious lesions, and that it had persisted not for the average period of an operation, but for hours and even days. The experience of the past war should not, however, be too hastily transferred to civil surgery. The conditions are obviously different, and it would be unwise not to have at hand an apparatus, other than the cumbersome and expensive chamber, for giving differential pressure anesthesia.

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CHAPTER XLII

SURGERY OF THE ABDOMEN AND PELVIS

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It is not the purpose of this chapter to make a conclusive presentation of the present status of abdominal surgery in its several aspects, but rather to note certain salient factors, and to summarize the lessons taught by military experience, in particular as they apply to civilian practice.

The conclusions presented here, therefore, are based not only on the experience of my colleagues, Dr. F. E. Bunts, Dr. W. E. Lower, Dr. H. G. Sloan, my associates on the Staff of Lakeside Hospital, and myself in 12,383 abdominal operations in civilian practice, but also on personal operative experience and observations with the British and American Armies in the field, and on the conclusions of the Interallied Surgical Congress.

Perhaps the one fundamental lesson that became increasingly emphasized by our experience in service with the armies at the front, in the field dressing stations, and in the base hospitals, was the fact that there exists no basic distinction between the war patient and the civilian patient; between the man exhausted by days and weeks of intensive fighting, of tense waiting, of dirt and wet, hunger and thirst, and the starved patient exhausted by the pain and distress of a chronic disease. It has been stated that among the dead left on the battlefield over 95 per cent. died from hemorrhage; that during the first twenty-four hours after they were rescued by stretcher-bearers approximately the same percentage died from shock; that after the first twenty-four hours the preponderant cause of death was infection.

The depression of hemorrhage and shock predisposes to infection and infection predisposes to secondary hemorrhage, local anemia, and a low general blood-pressure which are dangerous both because they lead to degenerative changes in the local tissue as well as in the sensitive brain, and because low blood-pressure diminishes the general resistance to infection.

It is obvious, therefore, that in the surgery of war as in surgery in the civilian clinic the prime problems are the same—shock, anemia, low blood-pressure resulting from hemorrhage, and infection.

SHOCK

We shall not consider here the pathology of shock, or the various theories of shock, but shall rather point out certain practical considerations relating to the treatment of shock as they have been developed

in the experience of the war. It may be in place to note, however, that these observations and conclusions are in accord with the conception that primary shock is due to an abrupt overwhelming stimulus —physical injury, intense emotion, acute infection, etc.—as a result of which the power of the brain cells to transform potential into kinetic energy is broken, and consequently the organism cannot perform its normal work. In consequence, metabolism collapses, the temperature is subnormal, and there is general prostration. Every normal individual has within himself large factors of safety. These factors may be diminished by want of food or drink; by exposure to cold or wet; by want of sleep; by a period of excessive muscular or mental work; by a prolonged emotional strain; by defense against chronic infection; by failure of elimination of waste products. If much of the normal margin of safety has been thus consumed, by so much the more readily will the individual succumb to physical injury—whether from a war wound or a surgical operation, to an emotional crisis, to an acute infection.

Whatever the cause of shock—whether psychic, traumatic, or toxic —the basic phenomena are the same. The individual is prostrated; his face is white and shrunken; there is no saliva, no gastric juice; the urine is scanty; the mind is dull; the temperature is subnormal. Thus the behavior and appearance of the man in shock is dramatically displayed—he is self-diagnosed. Laboratory observations have shown also that in shock from whatever cause the reserve alkalinity of the blood is decreased; that there are intracellular changes in the brain, the liver, and the adrenals; that the electric conductivity of the brain is decreased, and that the electric conductivity of the liver is increased. We have found also that fundamental restoration is accomplished only by rest, sleep, and warmth, aided by such measures as secure quiet and comfort; and that the processes of restoration may be aided by morphin, by fluids, and by any measures that will support and aid failing organs, such as securing proper ventilation for the lungs or blood transfusion to aid a failing circulation.

That the brain is the seat of the primary lesion in shock is demonstrated by the fact that surgical shock is wholly prevented by blocking the field of operation with a local anesthetic or by minimizing the response of the brain cells to the stimulus of traumatic impulses by nitrous-oxid-oxygen anesthesia. Nitrous oxid is almost a specific against shock, apparently owing this property to its interference with the use of oxygen by the brain cells.

In civilian surgery we have been too prone to consider that injury is the sole cause of exhaustion and shock. Military surgery, on the other hand, has supplied a mass of evidence which confirms what we have stated above—*i. e.*, that the severity and incidence of wound shock or of surgical shock depends in part upon other factors also, so that injury may be only one factor, perhaps even a minor factor, in the causation of any given case of shock. What are the more common causes which in the soldier may be additive factors in the production

of shock? The muscular effort, fear, and anxiety incident to battle cause the transformation of excessive amounts of energy, resulting in the formation of excessive amounts of acid by-products; the wound and its pain do the same; cold and wet depress oxidation; asphyxiating gas or an asphyxiating wound of the chest interferes with the normal supply of oxygen to the cells. If hemorrhage has occurred, the supply of food to the cells is interfered with, as is also the disposal of waste products from the cells. Thus hemorrhage adds its quota to the total interference with internal respiration.

Just as physical struggle, loss of sleep, emotion, exposure to cold and wet, and lack of food predispose to the production of shock by physical injury, or may of themselves alone be sufficient to cause shock or exhaustion, so also after an injury has been received, even if in itself it is not sufficient to cause shock, shock may be produced by the addition of other exhausting factors such as exposure to cold and wet; strain and worry lest further injury be received before rescue; augmentation of wound damage by efforts to escape capture; in cases of compound fracture, in particular, goading and injury in transport. Thus under battle conditions shock and exhaustion result from three general groups of causes:

1. The common causes of fatigue in combatant armies—those which effect the man before his injury is received.

2. The wound itself.

3. Hemorrhage and exposure after the wound is received and further injury in transport.

The military surgeon had no means of influencing the first two sets of causes, but it was within his power to mitigate some of the exhaustion-producing factors which followed the receipt of injury. To discover this means therefore became a prime matter of concern to all surgeons in military service.

In regard to abdominal surgery in particular, the Interallied Surgical Congress adopted the following general conclusions regarding the treatment of abdominal wounds in military practice:

1. The anesthetic of choice is nitrous oxid and oxygen combined with local anesthesia.

2. The best treatment for anemia after hemorrhage and shock is rest, fluids, morphin for pain, and blood transfusion.

Although the application of these conclusions will be discussed in later sections, it may not be out of place at this point to state that among the evidence offered in their support General Sir Anthony Bowlby presented the work of one of the most brilliant British military surgeons, Captain Douglas C. Taylor, and the work of the Chief of the Anesthetic Service of the British Army, Captain Gregory Marshall. The following statement by Captain Taylor I am privileged to quote:

"Until the summer of 1917 my colleague, Captain G. Marshall, invariably gave ether for my laparotomies for gunshot wounds of the abdomen. No series of 100 consecutive cases showed recovery rate of much over 50 per cent.

"During the summer and autumn of 1917 I did 101 laparotomies for abdominal wounds, and nearly half of them were given nitrous oxid and oxygen, combined with infiltration of the abdominal walls with eucain and novocain. The more serious cases—*i. e.*, those with rapid pulse and low pressure—were nearly all done by this method.

"Of this series, 27 died at the C. C. S. and 74 were evacuated to the Base; of the latter, there have been only 2 deaths, both from secondary hemorrhage—one from the kidney and the other from the rectum and buttock."

That is, by the employment of anociation* Dr. Taylor's mortality rate was reduced from approximately 50 to 29 per cent. (Fig. 364).

Captain Marshall, in turn, has demonstrated that patients may apparently do well during ether anesthesia, but do badly afterward, while they do well both during and after nitrous oxid-oxygen anesthesia (Fig. 365).

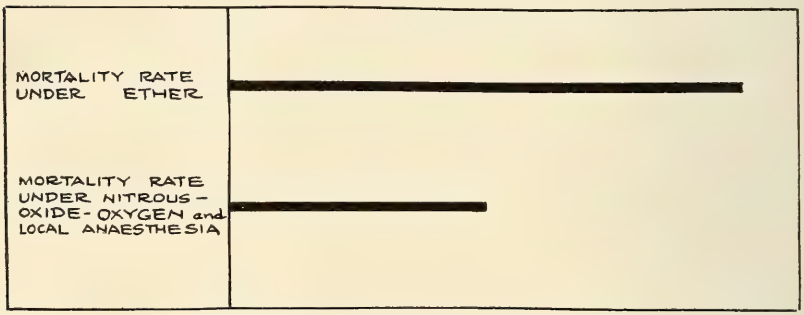

Fig. 364.—Abdominal Operations in Military Surgery.
Comparative mortality rates of operations under ether and under nitrous oxid-oxygen with local anesthesia (anociation). (From Captain Taylor's Statistics.)

In our experience in abdominal operations somewhat better results were obtained if, before the beginning of the operation, sufficient blood were transfused to permit a safe performance of the operation; and again at the completion of the operation an ample amount of blood up to 750 c.c. were given. Furthermore, if depression appeared later, the transfusion might be repeated. Meanwhile the advantages of comfort, rest, warmth, morphin, and fluids were added.

In this unparalleled opportunity the value of these agents as the most effective means of preventing and of treating shock and of combating the effects of hemorrhage was continuously demonstrated.

Civilian surgery and war surgery in their relation to shock present one important difference. The depleted civilian patient may be in a "preshock" state when he comes under the surgeon's care; the wounded soldier is often in shock. Nevertheless identical methods will prevent

* The term "anoci-association" was originally suggested by the author to define a state in which all noci-stimuli—traumatic and psychic—are excluded from the brain, this state being produced by a combination of general and local anesthesia, narcosis, and psychic management. The shorter term, "anociation," has been employed more recently as equally suggestive.

the development of shock in the first case and will successfully combat the shock present in the latter.

Physiologic rest includes mental and psychic, as well as physical rest. It means reassurance; it means an atmosphere of quiet and con-

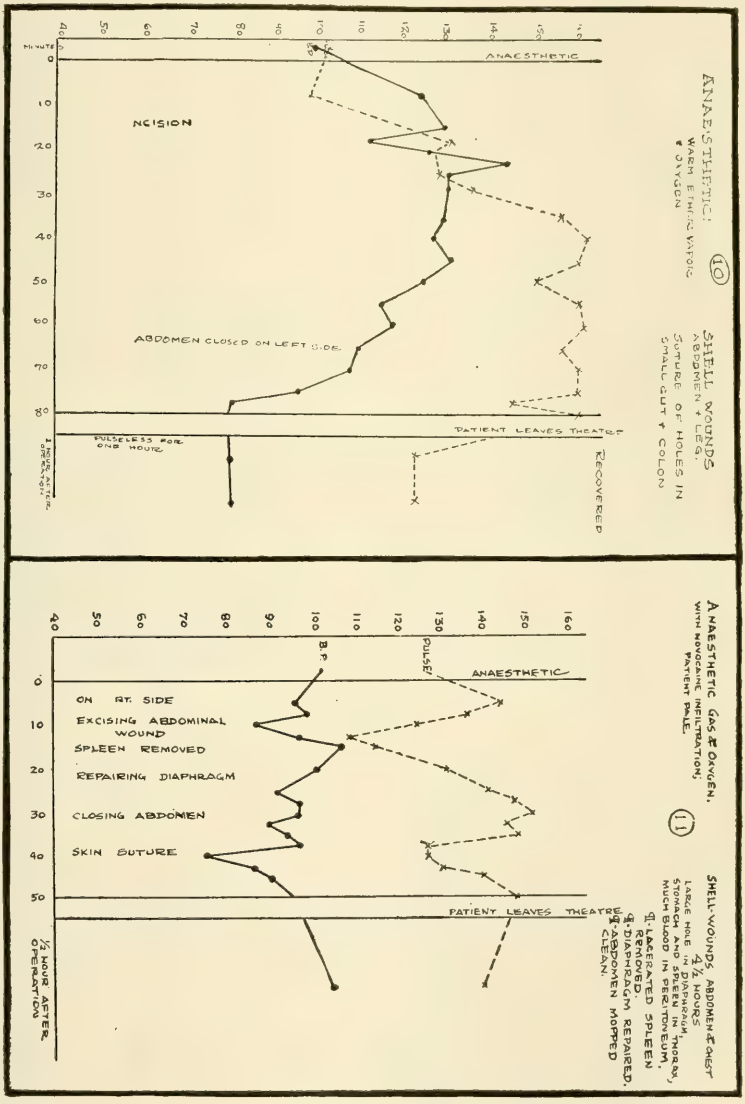

FIG. 365.—COMPARISON OF THE EFFECTS OF ETHER ANESTHESIA WITH THOSE OF NITROUS OXID-OXYGEN ANESTHESIA IN ABDOMINAL OPERATIONS IN MILITARY SURGERY.

A, Abdominal operations under ether. *B*, Abdominal operations under nitrous oxid-oxygen. (Courtesy of Captain Gregory Marshall.)

fidence; it means optimism as well as skill. Physiologic rest can be achieved only by the co-operation of surgeon, intern, nurse, and orderly.

Warmth.—The loss of power to create body heat is one of the damaging effects of shock, for the organism is much injured by a sub-

normal temperature. The application of heat, therefore, is one of the essentials of the treatment and of the prevention of shock.

Morphin.—If the patient has pain, if he is restless, and if the pain and restlessness cannot be otherwise relieved, then give morphin in $\frac{1}{6}$-grain doses until the pain and restlessness are overcome; there is also evidence that morphin in still larger doses is specifically useful.

Fluids.—Water in some form should be given, preferably by the mucous membranes. Sodium bicarbonate in a 5 per cent. solution and combined with 5 per cent. glucose administered by the Murphy drip is useful. In acute, grave cases, from 2000 to 4000 c.c. of fluid should be given each twenty-four hours either by rectum or in saline solution by hypodermoclysis. Water administered intravenously is rapidly eliminated from the body. Water absorbed through membranes or tissues is retained in much larger amounts. Water, to be most useful, should have a biologic pass.

Prevent and overcome the damaging effect of low blood-pressure (*a*) by elevating the foot of the bed; (*b*) by early transfusion of blood. Under war conditions donors for blood transfusion are usually numerous among the lightly wounded patients.

One of the greatest errors is to allow a patient to remain in a state of low blood-pressure in the hope that he will improve through his own resources, reserving a blood transfusion to be used as a last resort after it has become obvious that the patient is going to die. This is the same faulty logic that was once used in dealing with appendicitis. When the indication for operation in appendicitis was supposed to be a clammy, pulseless state, and the patient was dying, surgical treatment became almost discredited. It is equally illogical to wait for impending dissolution in shock before improving the circulation. Treatment should not be deferred until the inaugural state of death is established. There is another method of treating shock which is not generally applicable to war conditions, that is, deep narcotization with morphin—giving morphin on the same scale as in the Alonzo Clark treatment of peritonitis, *i. e.*, keeping the patient under morphin so completely that the respirations are down to from 12 to 15 per minute and the patient is deeply asleep. During this time one should give between 2000 and 4000 c.c. of normal saline infusion subcutaneously. When properly carried out, excellent results may be obtained by this method, which, however, should never be employed if there is cyanosis, never routinely, and always under expert supervision.

ABDOMINAL INFECTION

In civilian surgery the principal sources of infection are the appendix, the gall-bladder, the tubes, and perforating ulcers; or the infection may be incident to the operation itself.

In military surgery or in accidents the source of infection may be clothing, missiles, or the contents of the hollow viscera—especially the last.

In our military experience at the front and at a Base Hospital we found that the defense against infection in the soldier in many instances was greater than in the average civilian patient. The general resistance—the vitality of the soldier had been increased by his training—the open-air life, wholesome diet, regular hours, and physical exercise; and the muscles of the intestinal walls, like the muscles of the legs, had become larger and stronger. If the perforated hollow viscera had been closed, fresh soldiers, whose splendid general condition had not been greatly impaired at the time they were injured, rarely died of peritonitis. In the heavy winter campaigns death was due to bronchopneumonia, shock, exhaustion, etc., rather more commonly than to peritonitis. On the other hand, soldiers wounded after a protracted and exhausting season at the front, especially if cold and wet, as was almost universally the case during the winter months, with their general resistance lowered by bodily fatigue and mental stress—such cases bore operations for penetrating abdominal wounds badly.

The acute reduction of vitality in these fatigued soldiers is comparable to the lowered vitality of civilian patients reduced by chronic disease, such, for example, as cancer of the stomach.

The prime problem of abdominal surgery, then, is the problem of the patient with lowered vitality—reduced resistance—be that patient a wounded soldier or a diseased civilian. It follows logically that the first measure is to increase the general resistance. If immediate operation is not imperative the vitality of the patient may be increased by obvious measures—diet, fresh air, and, above all, *rest* and *sleep*—until a favorable condition for operation is attained.

In the soldier with perforating wounds, however, and in the starved civilian patient with partial obstruction, or with acute infection, operative measures cannot be postponed. In these cases the administration *per rectum* of a 5 per cent. solution of sodium bicarbonate with 5 per cent. glucose, and an immediate transfusion of blood may effect a sufficient restoration for the operation, or at least for the first séance of a two-stage operation under strict anociation—nitrous oxid-oxygen analgesia, local anesthesia, and the minimum amount of manipulation required to complete the operation, or in grave situations to make a sufficient anatomic adjustment to save the patient until an interim of rest and restoration has sufficiently increased his vitality to permit the performance of the second and major stage of the operation.

As for the technic of the operation, whether it be performed in one or two stages, whether it be the removal of an appendix or gall-bladder, resection of the stomach or colon, removal of tumors of the ovaries or uterus, or—in the wounded soldier—the repair of intestinal rents or perforations, every step should be under complete anociation—nitrous oxid-oxygen anesthesia or analgesia, supplemented by ether only when it is necessary to secure increased relaxation during the exploration, novocain infiltration, gentle manipulations, sharp dissection.

The essential points in the anociated treatment of abdominal infection, therefore, are the following:

1. Nitrous oxid-oxygen.
2. Anesthetized incision.
3. Accurate, clean-cut operation to diminish both infection and shock.
4. Adequate drainage.
5. Fowler's posture.

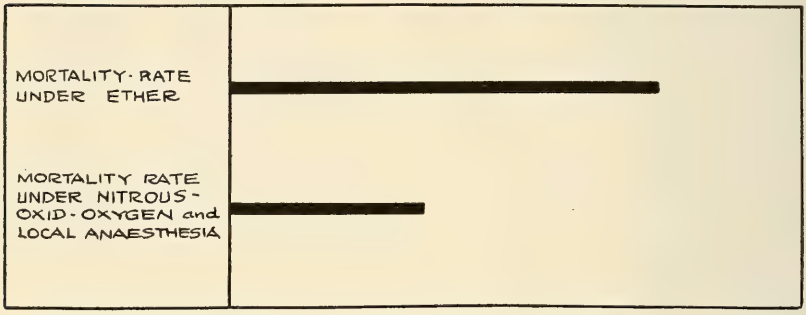

Fig. 366.—Abdominal Operations in Civilian Surgery.
Comparative mortality rates of operations for appendicitis under ether and under nitrous oxid-oxygen with local anesthesia (anociation).

6. Vast hot packs over the entire abdomen, spreading well down over the sides.
7. Five per cent. sodium bicarbonate, with 5 per cent. glucose by rectal tap, continued as long as it is tolerated.
8. Primary lavage of the stomach, repeated only if indicated. (It will rarely be indicated if *anociation* is complete.)
9. From 2500 to 3000 c.c. of normal saline subcutaneously every twenty-four hours until the period of danger is past.

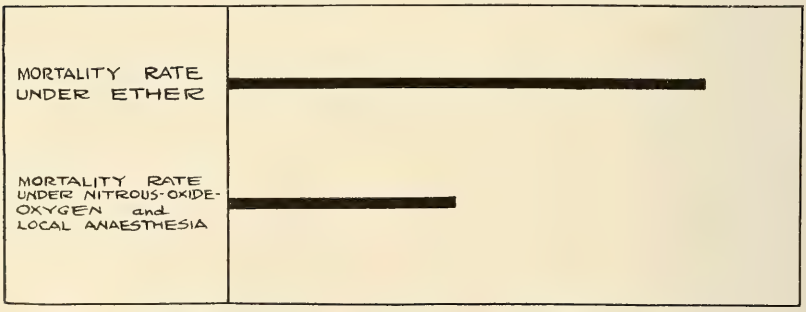

Fig. 367.—Abdominal Operations in Civilian Surgery.
Comparative mortality rates of operations on bad risks under ether and under nitrous oxid with local anesthesia (anociation).

10. Morphin hypodermically until the respiratory rate is reduced to from 10 to 14 per minute, and held to this rate until danger is past.

Under this combination of the anociation of peritonitis with the anociated operation, my associate, Dr. W. E. Lower, and I have performed 409 consecutive operations for acute appendicitis with or without generalized peritonitis without a death (Fig. 366).

With the foregoing principles established for the prevention and treatment of shock, hemorrhage, and peritonitis, which are the principal causes of death in abdominal operations, let us discuss their practical application to some of the principal groups of abdominal operations.

The most difficult and critical abdominal operations, carrying the highest mortality, are those for the repair of the perforating wounds received in war. It would seem, therefore, that a technic which can deal successfully with cases in which a bullet or shell fragment has torn its way through septic material into the hollow viscera in a soldier, who usually is in a state of physical and psychic exhaustion from fighting and delay, also often from bleeding, who is always infected, should provide even greater protection to the civilian patient, in whom avenues through abdominal walls and into viscera are opened by the surgeon under the utmost aseptic precautions at a chosen time and under planned conditions (Fig. 367).

Nevertheless, in the civilian as in the military hospital, the outstanding problems of abdominal surgery, as we have already stated, are infection, shock, and hemorrhage.

APPENDICITIS

First of all, we realize that the results secured by surgeons everywhere have improved. Our results have been so completely changed by a certain grouping of methods that we shall make these the special subject of our discussion. The cause of death from appendicitis is infection—local, general, pylephlebitis, or bacteriemia. Whatever may have been accomplished in the treatment of other forms of infection, there has been found no successful method of attack against bacteriemia *once it has become established.* Bacteriemia and pylephlebitis are quite *preventable,* however.

The adopted plan of treatment includes:

(*a*) Elimination of the danger from the inhalation anesthetic and elimination of the effect of surgical trauma.

(*b*) Special precautions against the occurrence of secondary abscesses.

(*c*) Prevention of pylephlebitis and bacteriemia.

(*d*) The anociated treatment of peritonitis, as outlined above.

The **anesthetic** is always nitrous oxid-oxygen—never even short ether, never supplemental ether. It is best, also, to use a local anesthetic in the abdominal wall.

Pylephlebitis.—This serious complication is now usually prevented, but when established it may be mastered by the following treatment: All surgical measures are withheld, and the patient is put on the dietetic and hygienic treatment for tuberculosis, so perfectly worked out by the internists. The patient is kept on a porch of the hospital as much as practicable, night and day, and nourishment is forced. Under this treatment there will rarely be a death. The time required for convalescence is about twelve weeks.

Bacteriemia.—As we have said, the only method of dealing with

bacteriemia is to prevent it by prompt, early operation; by breaking up no adhesions after vascularization.

In acute appendicitis we direct that the patient be propped up in bed, in the ambulance, in transit to the operating-room; that he be kept in an inclined position on the operating-table, *en route* from the operating-table to his bed, in bed until the danger of spreading infection is past. *The patient sits up throughout the progress of the disease.*

In these acute cases the incision is always over the center of the most tender area, always intermuscular. The peritoneal cavity is approached with the utmost care. If the abscess is localized, the operation is ended when the abscess is opened and gently explored. If the pus is free, then, regardless of the position of the appendix, the cigarette drain is carried down to the *left side* of the pelvis; the drain is carried along the bottom of the right pelvis, continues along the parietal peritoneum, and comes out at the lower end of the McBurney incision. This leads the pus from the left as well as from the right pelvis up to the opening. The Fowler position drains all free pus down into the pelvis, the cigarette drain directs the pus out of the pelvis, out of the abdomen; hence there are no residual abscesses in this territory. If the abscess is in the right loin, it is drained directly; this drain is not disturbed until the entire abdomen has settled down. The acutely inflamed appendix is picked up with the utmost gentleness and tied off near the cecum and excised—no invagination—nothing more. The cecum is left unmoved; it is not placed anywhere; it is allowed to stay where it is or to go its own way.

If there is a walled-off abscess, then the abscess is cautiously opened at its center, wherever that center is—McBurney, left, median, hypochondriac, umbilical—the abscess is opened in the center of the mass, the center of the rigid area and of the tender area. The appendix is tied and cut off wherever it is found.

The common cause of secondary abscesses, pylephlebitis, and bacteriemia is the opening up of absorption areas by the operation. The more carefully the tissues are handled, the more completely we respect nature's defense, the more rare will be these complications.

If the appendix has not been removed, when the patient recovers and the wound is healed—and such wounds soon heal because they have no complications—then by a clean intermuscular incision the appendix may be removed. The second operation is not indicated if necrosed portions of the appendix come away in the abscess. We have found that in the great majority of cases of acute appendicitis the appendix is removable.

The War Wound and Appendicitis—An Analogy.—In this discussion an interesting analogy between appendicitis and the war wound suggests itself.

1. In a case of acute *appendicitis*, if the dead appendix is removed before the infection has invaded normal tissue, then the wound is closed immediately, primary union follows, and the vast possibilities of inflammation of the great abdominal cavity will be averted. Like-

wise, if the dead tissue in the track of a *war wound* is excised before living tissues are invaded, the inflammation of a great mass of soft tissue will be averted.

2. In *appendicitis*, even after the infection has penetrated the wall of the appendix and invaded the peritoneum, excision of the dead appendix will facilitate recovery. In *war wounds*, even after the infection has passed beyond the devitalized tissue, excision of the devitalized tissue will facilitate recovery.

3. When an *appendicitis* has developed into a localized abscess, with an organized wall of granulations, the surgeon deals with the abscess as such. When the infection in a *war wound* has developed into an abscess with new tissue organization, no débridement is done, but the abscess is treated as such.

4. In the *war wound* the stage of contamination of dead tissue—the period before infection develops—corresponds to the period before infection from a dead appendix penetrates the wall. In this period if the dead *appendix* is excised cleanly, the case recovers; if the dead tissue of the *war wound* is excised cleanly, the case recovers.

5. *Appendicitis* and *war wound* infection develop through identical phases—localized infection, spreading infection, abscess.

6. If an *appendix* abscess is roughly handled, spreading peritonitis, pylephlebitis, bacteriemia, etc., may result. Comparable results follow when an infected *war wound* is roughly handled.

Appendicitis was not mastered until the surgeon had learned to forecast its future accurately and immediately—in other words, until he took the initiative away from the disease and attacked instead of defending. In like manner the military surgeon discovered that in the case of the war wound, as long as he left the initiative to the infection, he could not achieve mastery. To wait in the case of a devitalized war wound until the infection has spread widely—until there are pain, swelling, redness, and tenderness—is to court defeat. Like the tomorrow of the appendix, the tomorrow of the war wound must be read today, and action taken today.

An antiseptic does not cure appendicitis—it does not cure the war wound.

There is no difference in principle or in practice between the treatment of appendicitis and the treatment of war wounds. The time factor is equally vital; the treatment is comparable; the natural defense is identical.

OPERATIONS ON THE STOMACH

Two prime factors determine the result of operations on the stomach:

1. The state of partial starvation.

2. The degree of debility produced by the toxins of cancer and by hemorrhage.

The following suggestions are offered:

1. Establish an adequate water equilibrium by infusions.

2. If there is marked anemia, give an adequate transfusion of blood.

3. If the risk is extremely grave, use nitrous oxid-oxygen only to the extent of analgesia, and depend mainly on local anesthesia.

4. Make an ample incision so that the operation may be taken to the stomach, unless the stomach will come out easily.

5. If there is a cancer-like mass, and the hazard is great, then at the first operation make only a gastro-enterostomy; otherwise complete the operation in one séance.

6. In case of a two-stage operation, the resection may be made after the nutritional balance is well established, usually in about a week.

7. In the second operation not only will the resection be made with little disturbance, but as a result of the preliminary gastro-enterostomy there will be a strong mobilization in the operative field of the elements that produce local immunity against infection.

8. In certain cases it is impossible to differentiate cancer from ulcer by the symptoms and history, by *x*-ray examination, by palpation, even by the microscope. Thus in 4 of our two-stage operations the entire mass that at the time of the first operation—gastro-enterostomy—appeared to be cancer, disappeared before the second operation, so that the resection was not required.

9. In cases of cancer we have found in the second stage of the operation that the rest provided by the preliminary gastro-enterostomy has reduced the size of the growth by diminishing the inflammatory tissue.

10. In cancer it seems best to divide the tissue with an electro-cautery.

11. Use round needles for suturing the stomach.

12. Avoid postoperative hemorrhage by using the cobbler stitch.

13. Tie the interrupted sutures lightly.

14. Should there be postoperative nausea, use the stomach-tube promptly.

15. After the resection take especial precautions to keep the patient warm, and to keep up a good nutritional and water balance.

ACUTE CHOLECYSTITIS

Cases of acute cholecystitis usually can be carried over the critical stage into the subacute or chronic stage, but when operation becomes necessary in acute cases, the following plan is suggested:

Under only nitrous oxid-oxygen—never supplementary ether—and with local anesthesia the abdominal wall is divided over the exact center of the most tender, the most rigid area—not where the gall-bladder anatomically ought to be, but where the center of infection is.

The peritoneum is opened most cautiously and an attempt made to divide it wholly and only within the area of adhesion. If adhesions extend down to the distended gall-bladder, they are separated with extreme caution until the gall-bladder is reached, so that an aspirating needle may be inserted; the adhesions are separated only sufficiently to meet the absolute requirements for the establishment of drainage. As soon as the gall-bladder is opened (we are now discussing fulminant cases) drainage is inserted and nothing more is done surgically. A

quantity of iodoform gauze is lightly packed around the drainage, after which large pieces of gauze are inserted around all the sides of the short abdominal incision. No stitches are used, provided the incision is short and the gauze packing adequate. As a result, the infection collapses, and rapid convalescence follows. After all the acute symptoms have subsided, the temperature has remained normal, and the patient has been in good condition for a sufficiently long period, then a cholecystectomy is performed.

RESECTION OF THE LARGE OR THE SMALL INTESTINE

Gangrene resulting from acute intestinal obstruction and the presence of cancer are the two conditions for the relief of which a resection of the intestines is most frequently indicated. Whatever the condition, the first step is an operation for immediate relief. This point has been especially emphasized by Dr. J. E. Summers.

The following points in the technic of resection of the intestines may be mentioned:

1. Moynihan's plan of dividing the peritoneal attachment of the colon is most useful, as this mobilizes the colon to a great degree, and permits easy handling with minimum manipulation.
2. Use silk sutures.
3. Use round needles.
4. If there is plenty of room, close the divided ends and make a lateral anastomosis.
5. The second choice is end-to-side anastomosis.
6. The last choice is end-to-end anastomosis.
7. If anatomically feasible, protect the suture line with omentum.
8. In very grave cases perform the operation in two stages.
9. Relief from obstruction is the first consideration.
10. The newer methods of control will minimize danger from infection.

In all cases of cancer of the rectum a two-stage operation is performed. In the first operation, under anociation, the incision is so placed as to allow complete information regarding the local extent and also the dissemination of the cancer to other parts, especially to the liver. If the case is operable, a Littlewood artificial anus is made—*i. e.*, by an intramuscular incision below the border of the ribs—and the operative field is surrounded with gauze lightly impregnated with iodoform. Perhaps the most practical plan for the management of artificial anus is that devised by a patient of Dr. W. W. Keen* (Jour. Amer. Med. Assoc., Aug. 3, 1898). These procedures involve a light and a short operation. After the physiologic action of the artificial anus is established, and the patient's condition is satisfactory, usually within four days, then the excision of the cancer is made. Since the first operation, usually under analgesia, has caused but little disturbance, the patient looks forward to the second with relative equanimity.

The surgeon, too, may anticipate the second stage with equanimity

* See also Chapter LXIV in this volume.

because of the many safeguards he is able to offer, principal among which are the following:

1. The iodoform gauze, which mobilizes a strong defense against infection.

2. The improved methods of combating infection and promoting the healing of wounds which have been evolved in war surgery.

3. The control of shock.

4. The established, functioning anus, by which the new wound is completely protected from feces.

5. The continued, unhampered nutrition.

6. The resort to blood transfusion, if anemia or exhaustion or hemorrhage wears down too much the resistance of the patient.

7. The promotion of the welfare of these cases of tardy repair by a dietetic and hygienic regimen similar to that for tuberculosis—forced feeding and fresh air in abundance.

Since the foregoing plan has been followed the author has performed 38 operations for cancer of the rectum, 20 of which have been radical, without a death.

PERFORATING WOUNDS OF THE ABDOMEN AND PELVIS

The length of time between the receipt of an abdominal wound and arrival at the hospital is a vital factor, as after the tenth hour the prognosis becomes progressively worse until the twentieth hour, when, as a rule, the established infection makes operative measures inadvisable. That abdominal cases should be held at the front until danger of peritonitis is past, that is, from ten days to two weeks, according to the nature of the wound and operative procedure, is the consensus of opinion of the staffs of 35 military hospitals. Owen Richards (Brit. Med. Jour., April 27, 1918) points out that "of the patients who survive operation performed in the first twelve hours a high proportion will have had their lives saved by it, and this is true in a lesser degree of those operated on in the second twelve hours." The vital need of expert surgical judgment is also emphasized by Richards: "The real failures are the cases in which the patient is classed as moribund when operation might have saved his life, and those in which a penetrating wound of the abdomen is not recognized as such until it is too late" (Ibid.). The importance of the recognition of this factor—early operation—in civilian practice was indicated at one of the sessions of the Research Society of the American Red Cross in a portion of General Makins' response to the query "What effect will military surgery have upon civilian work at home?" "In civil life we should always open an abdomen and in certain cases get successful results as in the army. *It is only in this war that facilities have been provided for taking the cases early enough*" (War Medicine, Vol. II, No. 7, Feb.–Mar., 1919, p. 1280).

In a desperate case, therefore, in which the vitality of the patient has been greatly reduced by exposure, starvation, fatigue, or hemorrhage, a transfusion of blood is first given and the abdomen opened at

once under nitrous oxid-oxygen analgesia and local anesthesia, to establish drainage and accomplish the *immediately essential anatomic repair*. The final operation may then be postponed until the patient's reserves are sufficiently restored. It cannot be too strongly emphasized that this is the one absolute rule for the treatment of penetrating wounds of the abdomen—*immediate operation*. All abdominal cases should be moved as little as possible. It was to meet the urgent need of these cases in particular that mobile field hospital units were planned. These units by following the lines of battle could give immediate care to critical cases, and could retain them until they could be safely removed to the base hospital.

COMPARATIVE EFFECTS OF LESIONS OF THE SOLID AND OF THE HOLLOW VISCERA

Lesions of the liver and spleen are far less grave than lesions of the hollow viscera. Generally speaking, surgical intervention is not indicated for lesions of the liver or of the spleen except for the control of hemorrhage. For the control of progressive hemorrhage from the liver gauze packing has proved preferable to attempts to suture. Badly shattered spleens are best excised. An extensively injured kidney should be removed; a local wound may be successfully treated by a local resection, and covering the field of suture with renal fat. A torn pancreas should be drained widely and mutton tallow, if available, applied about the wound.

Lesions of the large intestine resulted in a higher mortality than lesions of the small intestine. In cases of gunshot wounds of the small intestine it was surprising to find to what extent, in many cases, leakage was controlled by the contraction of the intestinal wall. As to mortality, lesions of the stomach were comparable to lesions of the small intestine.

Combined thoracic and abdominal wounds are especially grave. The practical point to note in these cases is that the thoracic approach is usually better than the abdominal approach, provided there are no perforations below the stomach.

Among the conclusions of the 3d Interallied Surgical Conference are the following (Med. Bull., Paris, I, p. 80):

"In wounds of the abdomen and thorax the wound of the diaphragm constitutes the specific factor of the lesion; the wounds of the organs of the abdomen and thorax present no special anatomic interest.

"Hernia of the abdominal organs is difficult to recognize clinically. Radioscopic examination reveals the displacement of the heart to the right, and so helps in diagnosis so far as the left side is concerned.

"Indications for operation are absolute except in the case of a very small projectile in the upper part of the abdomen, especially at the right. The perforation of the diaphragm in itself necessitates suture.

"Approach by way of the pleura affords especial advantage for exploration of the lesions, and also for treating the pleural cavity or for suturing the diaphragm. It permits also the treatment of lesions in

the abdominal organs, beneath the diaphragm, whether there is hernia or not.

"A separate laparotomy may sometimes be necessary.

"The opening of the thorax and abdomen by a single incision permits generous treatment of both chest and abdominal lesions." (Compare the chapter on the Surgery of the Chest.)

When the missile has passed through the large intestine and through the retroperitoneal area, one of the most dangerous conditions exists, because the retroperitoneal area has a very low power of resistance to infection. If this applies to the ascending or descending colon, then, after repairing the visceral injury, the incision is carried laterally to the exit tract, which is excised. Carrel-Dakin tubes are inserted into the retroperitoneal space and the abdomen closed. Perforations of the stomach and of the small intestine are more readily repaired than perforations of the large intestine.

WOUNDS OF THE PELVIS

According to Tanton* isolated wounds of the bony pelvis represent about 1.06 per cent. of all war wounds. In his report before the Second Session of the Interallied Surgical Conference he offered the following table showing the distribution of lesions among 3783 cases:

	Recent.	Old.
Iliac bodies	1659	199
Iliac crests	311	43
Sacrum	652	62
Coccyx	24	1
Sacrum and coccyx	21	4
Wing of sacrum	20	2
Sacro-iliac area	120	41
Pubic bone	202	12
Pubic symphysis	12	2
Pubo-ischial ramus	47	10
Ischium	241	29
Ilium and others	60	9

According to Tanton the treatment may be summed up briefly in the following dicta: "Débridement in early cases. Excision with well-arranged drainage in late cases."

In pelvic wounds, in which the rectum or bladder or both are involved, plastic operations are deferred until infection is controlled. As to the operation itself, the technic does not vary in any important detail from that which is indicated for rectal or vesical operations in civilian practice.

The judgment of the members of the Fourth Interallied Surgical Conference as to pelvic wounds is summed up in the following conclusions adopted at its fourth session†:

"I. **Simple Wounds of the Pelvis.**—Treatment depends on the general therapeutics of war wounds of the soft parts or bones. Comminutive fractures of the ilium, particularly, require wide trephining.

* War Medicine, vol. ii, pp. 80, 235.
† Ibid., vol. ii, No. 1, August, 1918, p. 61.

"The extraction of projectiles (splinters are often driven in the psoas iliacus) is very difficult and must be done systematically.

"II. **Wounds of the Bladder.**—(*a*) **Intraperitoneal:** Justify a laparotomy and suture; (*b*) **extraperitoneal:** Suprapubic wounds can be treated by primitive vesical suture.

"The wounds of the walls and base of the bladder, which cannot be reached by operation, do not require an immediate systematic cystostomy. The surgical treatment of the entrance wound and of its direction insure sufficient drainage.

"III. **Wounds of the Rectum.**—(*a*) **Intraperitoneal:** Like all intestinal wounds, these justify laparotomy with suture; (*b*) **extraperitoneal:** In the majority of cases treatment consists in the revision of the wound, followed by plugging of the rectal wound.

"Constipation of the patient is an indispensable adjuvant.

"In splintering with extensive separation, the fixing of the rectum, completed if necessary by a posterior rectotomy, will be the treatment of choice. Primitive colostomy has very exceptional indications.

"IV. **Associated Wounds of the Bladder and Rectum.**—The majority of these heal up after the surgical treatment of the extravesical direction of the projectile. Colostomy should be reserved for very large vesicorectal openings.

"Primitive cystotomy is very often useless. The retention sound, ventral decubitus, micturition in the genu pectoral position favor spontaneous healing of the vesicorectal fistula."

SUMMARY

General experience in abdominal surgery in the World War with its special application to civilian surgery may be summarized as follows:

1. Soldiers whose general condition had not been too greatly impaired by exhaustion from fighting, by wet and cold, or by shock or hemorrhage showed a resistance to infection rarely seen in civilian surgery. There seemed to be as marked an increase in the firmness and the thickness of the muscles of the intestine of the average soldier as compared with the average civilian patient, as the leg or arm muscles of the soldier were larger and firmer than those of the civilian.

2. Soldiers wounded after a protracted season at the front, especially if cold and wet, as was almost universally the case during the winter months, with their general resistance lowered by bodily fatigue and mental stress, bore penetrating abdominal wounds badly.

3. The length of time between the receipt of the wound and arrival at a hospital was a vital factor. After the tenth hour the prognosis became progressively worse until the twentieth hour, when, as a rule, the established infection made operative measures inadvisable.

4. That the importance of immediate operation and of postoperative rest was recognized early in the war is indicated by the following conclusions adopted by the Interallied Surgical Conference in April, 1917*:

* The Medical Bulletin, vol. i, p. 25.

"(*a*) On general principles, all recent wounds of the abdomen should be operated on except when the lesion is without doubt limited to the liver or the kidney, and when there is no symptom of serious hemorrhage.

"(*b*) The operation should be performed *as early as possible*, except when the patient is suffering from shock. When there is doubt as to the relative seriousness of the shock and that of the hemorrhage, it is better to operate. Do not make a practice of laparotomy later than thirty-six hours.

"(*c*) Centers should be established as near to the lines as possible, *provided with all surgical appliances which are now recognized as necessary*, where all cases of abdominal wounds may be taken for operation by competent surgeons."

5. The two outstanding phenomena of internal hemorrhage are a mounting leukocytosis and a falling temperature; the treatment includes operation, morphin and blood transfusion, the giving of fluids, and keeping the patient warm.

6. The best treatment for hemorrhage and shock is heat, rest, fluids, morphin, and blood transfusion.

7. In abdominal surgery the general experience was that, during the winter months, there were more deaths from bronchopneumonia than from peritonitis. In certain winter campaigns, on account of the fatigue of the troops from heavy front line duty, from cold and wet and difficult surroundings, the incidence of bronchopneumonia was so high that operations were temporarily suspended.

8. In military, as in civilian surgery, retroperitoneal infections carried a higher mortality than intraperitoneal infections.

9. The technic that will deal successfully with the exhausted, infected soldier with a perforation of the intestine will be of equal value to the exhausted civilian patient.

10. Special points in technic:

(*a*) Assuming good technic, as compared with a rapid operator a slow surgeon has a high mortality.

(*b*) Sutures are easily tied too tightly.

(*c*) No drainage is required in operations on the small intestine. In operations on the large intestine drainage may be used, but never in contact with the line of suture.

(*d*) Retroperitoneal infected wounds should be treated by the Carrel method.

(*e*) The abdominal wall may be divided in any direction with impunity.

(*f*) Although not every perforated abdomen holds perforated viscera, every perforated abdomen should be opened.

We have seen patients whose abdominal wall had been torn wide open, and whose intestine was cold, covered with mud, and perforated, get well under the management outlined.

CONCLUSION

The personal military experiences upon which the foregoing summary is based were with the British in Flanders in 1917, and with the American forces in the Argonne in 1918. The outstanding conclusion from this experience is that the general principles which govern the successful handling of the problems of abdominal surgery are the same in military as in civilian practice. A good abdominal surgeon in military surgery will be a good abdominal surgeon in civilian surgery, and vice versa.

CHAPTER XLIII

APPENDICITIS *

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Since the publication of the original contributions to this System of Surgery on appendicitis its famous author has been taken from his earthly labors. Surely his reward must be great if measured by his unceasing search for truth, his ardor in disseminating that which be believed to be right, his keen judgment almost amounting to instinct which never permitted him to stray far from the straight path, and the great influence which his personality and the mastery of the subject of his life's work enabled him to wield in the struggle against disease and for the welfare of his fellow-man. John B. Murphy will remain one of the outstanding figures of surgery for all time.

It is not surprising then that the contribution from his pen should, on close examination after a decade, be found to contain little which permits of change or to omit much that is of first importance. Appendicitis in its highest surgical development at that time may now almost be said to be in *statu quo*. Still the wide dissemination of that knowledge is far from complete, and in certain particulars increased experience has enabled us to speak with even greater positiveness and at times to alter somewhat in detail the conclusions of that day.

As showing the importance of the subject it may be said that the field of surgery of the appendix has enlarged rather than contracted since Murphy's day.

Chronic Appendicitis with Referred Symptoms.—The frequency of functional disorders of the gastro-intestinal tract consequent upon disease of the appendix was less emphasized in the original article than the importance of the subject deserves. Murphy was not unaware of the existence of this class of cases, and it was about at the time of the publication of his contribution that international discussion concerning them became rife, the great abdominal surgeons of this country taking a leading part. Various names were proposed to cover the condition, such as "appendicitis larvata" (Ewald), "Appendix dyspepsia" (Moynihan), and "appendicular gastralgia" (Paterson). We have preferred to speak of it by a longer term, since it is more inclusive and covers not only the secondary disorders of the gastro-intestinal tract and its derivatives but also the genito-urinary tract and the pelvic organs which are not uncommonly affected.

* Supplementary to Chapter LXIII, Vol. IV, p. 727, and Chapter CXXVI, Vol. VI, p. 540.

It is now a matter of common remark by surgeons, though not yet sufficiently appreciated by the profession at large, that chronic appendicitis may fail to reveal itself by local signs or symptoms, wearing instead the mask of gastric, duodenal, or cholecystic disease, or of affections of the small or large intestine, or of chronic pelvic disease, or, less frequently, of disorders of the urinary tract. Most commonly disease of the upper abdominal viscera is simulated. The definition of Maunsell is excellent: "It is a group of symptoms and perhaps signs which point so strongly to organic gastric or duodenal disease that it is only by most careful examination or by the supervention of definite appendicular symptoms that a correct diagnosis is probable." If this statement were extended to include the other organs above mentioned it would suffice for a definition of chronic appendicitis with referred symptoms.

The pathologic basis for these varying conditions may be found to be an uninflamed appendix which is fibrous, obliterated, strictured, kinked, adherent, subcecal, or concretion containing. The *modus operandi* is either by the reflex arc or by means of absorption of toxins or micro-organisms. Motor, secretory, and sensory phenomena may be produced, and as a still further result actual pathologic alterations may occur. Such at least is the strongly supported clinical inference. It is impossible as yet to parallel these obscure clinical conditions with artificial experiment. That pylorospasm may exist as a result of disease of the appendix there can be no reasonable doubt. Commonly the gastric secretions show variations from the recognized normal. There is, however, no rule as to the type of variation. When pylorospasm exists there is ordinarily delay in the passage of food through the stomach, and hyperacidity is the rule. Not infrequently, however, there is hypermotility of the stomach and subacidity of the contents. The snares of diagnosis by gastric contents are now well known, and it is necessary only to remind the physician that abnormal findings may be due to no intrinsic disease or impairment of function of the stomach itself, but merely to the effects of a diseased condition of the intestinal tract lower down, and in this connection the appendix is always to be considered even in the absence of clear-cut symptoms or signs of appendicitis. The more obscure the cause of chronic indigestion, the greater the likelihood that a diseased appendix is the cause of it.

The lower intestinal tract also may be the means of expression of chronic disease of the appendix. Constipation is most common, but frequently alternating constipation and diarrhea are present. Colitis is occasionally the incorrect diagnosis in this condition. Symptoms simulating renal or ureteral involvement are most often due to the retrocecal appendix, but at times may be present without actual proximity of the appendix to either the kidney or the ureter. It is probable that retroperitoneal inflammatory processes or changes secondary to lymphatic involvement from an infected appendix may be responsible for the symptoms.

The complete understanding, diagnosis, and treatment of this type of appendicitis are much complicated by the fact that disease of the

organs mentioned may coexist with appendicitis as an independent lesion, and also that there is a strong suspicion based chiefly on clinical grounds that appendicitis may be the ultimate cause of actual organic lesions in the organs under consideration. Thus the frequent coincidence of chronic appendicitis with gastric and duodenal ulcer and cholecystic disease has excited the attention of all leading abdominal surgeons. Much discussion has resulted. Dieulafoy believed that appendicitis might not infrequently be due to cholecystitis. Lane and others advance the idea that the disease of both is due to a common cause. It is not improbable that instances of this sort occur. However, we believe that the appendix which is so commonly diseased alone, so far as clinical or other evidence indicates, is usually the first offender, involving other organs by sepsis, toxic, or reflex nervous phenomena.

Routine removal of the appendix whenever the abdomen is opened receives strong support from this conception of the pathogenesis of associated abdominal lesions. Murphy reported Kelly's questionnaire to 80 surgeons in respect to this question. At that time, of 70 answers, 26 were *pro* and 45 *contra*. Kelly argued against it on the grounds that (1) it prolongs time of operation; (2) increases shock; (3) makes the risk of operation greater, and (4) may harm the individual by loss of a physiologic function of which we are not aware at the present time. Murphy favored removal only where there were definite pathologic changes or where there was a history of previous attacks.

We are certain that today a large majority of surgeons favor "hanging on sight." In the hands of an experienced surgeon the operative shock is practically nil. No additional support of the theory of physiologic function is as yet forthcoming. Finally, if pathologic changes are the criteria, practically every appendix should be removed, as all show pathologic changes on critical microscopic examination. The fact is, that *active* pathologic processes which would be a reasonable criterion if recognizable by the gross appearance cannot always be so determined. Moreover, the important matter of prevention was not considered. We have recently observed a young man sent to the University Hospital moribund as the result of streptococcic peritonitis secondary to perforated appendix. He gave a history of having been operated upon for duodenal ulcer two years previously. Many similar cases can be recalled, most of them, fortunately, not fatal. On the other hand, in the incidental removal of several thousand appendices we do not recall one complication or fatality that could justly be attributed to this part of the procedure, while by acting upon this principle we have removed a considerable number of appendices which showed upon finer examination active inflammatory processes, several carcinoids of the appendix and large numbers of partially strictured and obliterated appendices which in a fair proportion of cases are productive of symptoms. In fact, so protean are the manifestations of chronic disease of the appendix that in most of the surgical diseases of the abdomen exclusive of malignant disease we would not feel satisfied that we had satisfactorily

treated all causes of the condition unless the appendix also had been removed.

The diagnosis of the masked variety of chronic appendicitis is usually difficult and, as already stated, may be impossible to make with any degree of certainty. The most constant and reliable sign is tenderness over the site of the appendix. This is best determined by fingertip palpation and comparison with the opposite side. At times the overlying muscles show slight increase of tension and some spasm ensues when the tender point is palpated. The cecum is often distended with gas. A thickened appendix in an individual with thin, relaxed abdominal walls may at times be palpated, but this bit of evidence is difficult to obtain and is often misleading. Morris describes a tender point slightly internal to McBurney's point which he believes to be the situation of ganglia that become irritable and tender as a result of chronic appendicitis. It is true that at times the tender point is found in this situation. Rovsing's and Bastedo's signs are of little value in this condition. Temperature, as a rule, is normal. The leukocyte count is often a high normal, or slightly increased, varying from 7000 to 9000. Recently it has been claimed that the transitionals are relatively increased. We are unable to confirm this. At times even the valued sign of tenderness is lacking.

In the absence of fairly definite signs of involvement of the appendix it is not often wise to resort to operative interference with the object of simply removing the appendix. Such cases should be subjected to an extensive general diagnostic study, for if it is true that chronic appendicitis may simulate simple indigestion and disease of other organs, it is also true that many other conditions, both general and local, may produce the same indefinite abdominal symptom complexes. To operate hastily, therefore, is to court disappointments. Systemic and extra-abdominal organic disease should be excluded. Within the abdomen one must consider affections of the right urinary tract, visceroptosis, intrinsic diseases of the stomach, duodenum, gallbladder and pancreas, visceral tuberculosis, rheumatoid arthritis of the spine, psoas abscess, hernia, especially the inconspicuous epigastric variety, adhesions and bands which interfere with peristalsis. If general disease of a sort to explain digestive disturbance be lacking, and if other organic abdominal disease be excluded, it is wise to observe the patient closely for a period. Usually at some time and especially during exacerbations of symptoms local signs of disease of the appendix, chiefly tenderness, may be elicited.

Acute Appendicitis.—Since our methods in the treatment of acute appendicitis differ in several important particulars from those of Murphy, it will be best to state our position rather than to attempt to limit discussion to points of difference.

From the standpoint of treatment cases of appendicitis may be divided into:

(1) Simple appendicitis without peritonitis.

(2) Appendicitis with peritonitis.

It is a commonplace that simple appendicitis is prone to pass on to the stage in which it is complicated by peritonitis. Since appendicitis derives its lethal character from the peritonitis to which it may give rise, the argument for early operation is unanswerable, though not always heeded even yet. The time factor is so important that we may divide our cases again, with a view to formulating rational methods of treatment, into

(1) Early.
(2) Delayed.
(3) Late.
(4) Interval.

The ideal early case of acute appendicitis is brought to operation within the first few hours of the attack in which the inflammation is still confined strictly to the appendix. No artificial time limit can be set upon this period. Murphy's statement that "during the first forty-eight hours, and particularly in the first thirty, the disease is confined within the limits of the appendix" is too dogmatic and dangerous. Many cases show a well-developed peritonitis by the end of forty-eight hours and occasionally within twenty-four hours. The rapidity with which peritonitis makes its appearance depends upon the virulence of the infection of the appendix and the occurrence of perforation, gangrene, or migration of the micro-organisms through the walls of the inflamed appendix. The term "early" should be restricted to those cases which are as yet uncomplicated by peritonitis. Cases which have developed peritonitis may be early in point of time and early so far as the peritoneal process is concerned, but they are *delayed* with reference to the disease of the appendix. The earlier the operation after the beginning of peritonitis, the more nearly does the mortality approximate that of simple acute appendicitis, which should not be greater than 0.2 to 0.5 per cent. The later it is deferred, the greater the variety, and the more serious the nature of the pathologic conditions that may make their appearance. In early appendicitis and in the early stage of appendicular peritonitis the operative treatment is simple appendectomy. In the later stages of appendicular peritonitis the decision for or against immediate operation and with reference to the procedures to be adopted will vary with the clinical and pathologic conditions. A thorough understanding of the pathology of this form of peritonitis is necessary to deal properly with the individual case.

In the first stages of appendicular peritonitis the appendix is not shut off from the general abdominal cavity by enveloping adhesions. The immediate and adjacent peritoneal surfaces, being irritated by the bacterial invasion, pours forth a serous fluid which soon becomes cloudy with leukocytes and, finally, purulent. Also when the irritation and inflammatory reaction of the peritoneum is sufficiently severe a fibrinous deposit appears on the peritoneal surfaces most affected. This deposit tends to cling to adjacent surfaces and thus to glue them tightly together. These processes vary infinitely in rapidity, degree, and detail. They may stop at any point and undergo regressive changes.

Coincident with the pathologic processes there are interference with intestinal function, reflex phenomena, and systemic disturbances due to the *tout ensemble* of nervous, inflammatory, and toxic conditions.

The trend of the pathologic process is toward one of three terminations, namely: (1) subsidence by absorption, (2) generalization of the peritoneal infection, or (3) localized abscess formation by the deposition of lymph and agglutination of omental, visceral, and parietal peritoneum about the area or areas of greatest infection.

Subsidence by Absorption.—Candor and fact compel the admission that many, perhaps even a majority of cases of appendicitis will recover from a single attack as a result of the defensive powers of nature unaided by treatment of any kind. When the principles of "physiologic rest" are applied a still further percentage may be saved. To admit this is but to testify to the great protective and healing power of nature, without which surgery and medicine alike would be helpless. On the other hand, nothing is better substantiated than that a very considerable proportion of cases of appendicitis will, in spite of every known means of aiding the natural curative powers, short of operation, go on to the development of peritonitis or abscess formation. Moreover, spontaneous recovery without removal of the appendix exposes a majority of cases to recurrence of the disease. It is utterly beyond the skill or wisdom of any man to predict a favorable outcome in any case by means other than operative. The victory of surgery in the treatment of this condition is complete, and no internist, gastro-enterologist, or general practitioner should attempt to treat a case of appendicitis without surgical advice. Unless this be universally admitted, it is far better to insist upon invariable and immediate operation in every case as soon as the diagnosis can be made and the patient seen by the surgeon, since it is only by the complete triumph of surgical direction in dealing with the disease that the lowest mortality can be attained. This was Murphy's principle, and none can take exception to the beneficent results of its application.

Ochsner, however, with acute clinical vision, saw that there was a small minority of cases which could best be treated by delay in operation until a more favorable condition could be brought about. This proposal was hailed by advocates of non-operative treatment as a medical means of dealing with appendicitis, and was distorted into an excuse for delay in the surgical treatment of appendicitis in general, than which nothing was further from Ochsner's thought. At the other extreme were surgeons who denounced delay in any case, rightly recognizing that delay in operation was the source of almost the whole mortality in appendicitis, and therefore unflinchingly refusing to countenance it under any circumstances. Abdominal surgeons of great experience, however, early saw that there is, in reality, a group of cases that are unfavorably influenced by operation. It has been well pointed out that the term "early" as used in the cry for early operation does not truly relate to the time the case is first seen by the surgeon, but to the time of commencement of the disease. As Maurice Richardson

said, there are cases that are "too late for an early operation and too early for a late operation." In our opinion, there is no question that there are cases that die if operated upon at once who can be saved by judicious preliminary treatment followed by operation. The recognition of these cases is not always easy, and their definition in descriptive terms is exceedingly difficult. We have come to look upon this question as the *pons asinorum* of the abdominal surgeon.

Let it be understood at the outset that there is every argument for and no argument against immediate operation in the early stages of appendicular peritonitis. In general, it may be said that all cases seen within the first twenty-four hours, and with but very few exceptions all cases seen within the first forty-eight hours after onset should be operated upon at once. The appendix should be removed and drainage instituted if necessary. In this stage there are no limiting adhesions about the appendix, which is the portal of entry of infection to the peritoneum. If the infecting agent be removed the peritoneum can deal with the usual type of appendicular infection. If the peritoneal exudate is not too abundant or vicious in character, and if the tissues in immediate contact with the appendix are not gangrenous or deeply infected, the abdomen may be closed in the confident expectation that the case has now been placed in the first category, and "subsidence by absorption" will occur. If, however, the exudate be purulent or in large amount and tissues of doubtful viability be found, it is safer to employ drainage for the double purpose of conveying infective materials to the surface and of establishing a tract from the dangerous focus to the surface which speedily becomes walled off from the general abdominal cavity. Again, the peritoneum deals successfully with the lesser degree of infection in the outlying areas, and recovery ensues with sinuses that close later with proper treatment. In a community well informed and properly alive to the dangers of appendicitis the majority of operations for the acute disease will be done in the stage just outlined. They are delayed in the sense that beginning infection of the peritoneum is present. They are early in so far as the peritonitis is concerned. They present a good prognosis, though not so good as in the truly early cases with inflammation still limited to the appendix. The mortality should not be greater than 1 to 3 per cent.

Cases not seen until the latter part of the second day after onset or later present various conditions. They may be apparently subsiding. It is never wise to trust to clinical appearances to determine this fact, since it is well known that gangrene of the appendix may cause a deceptive temporary subsidence of symptoms. Also perforation may be imminent, for which no symptomatology exists. If operation discloses subsidence, both the surgeon and the patient may be thankful, as it insures speedy and safe convalescence and security from future trouble. On the other hand, though not usually before the third or fourth day, abscess formation may be evident with the existence of a definite mass, the remaining portions of the peritoneum showing little or no inflammation. Such cases should be operated on at reasonable convenience.

The technic will be discussed later. It is the cases in the intermediate stage, which give evidence of a wide-spread peritoneal infection, that cause us the greatest concern and involve the question of immediate *versus* delayed operation. When the general condition of the patient is good, the signs of toxemia not marked, and the evidence of peritoneal mischief confined to the locality of the appendix, operation should be undertaken at once. When, however, the patient gives evidence of being hard hit, the facies suggestively Hippocratic, with the systemic signs of marked toxemia, rapid pulse, fever above 102° or 103° F., sometimes capillary stasis or even cyanosis, the abdomen tender generally or at least in the entire lower half, spastic, distended, peristalsis diminished and tinkling, experience has shown that immediate operation will often precipitate a fatality. A typical case of this kind is as follows:

Mrs. E. L., aged twenty years, was admitted to hospital March 31, 1919, complaining of general abdominal pain. Two days (fifty hours) prior to admission she was seized with sharp, sudden pain in the abdomen, followed by vomiting. The pain has been almost continuous and quite general since that time. At the beginning of the attack she took a purgative.

On admission she presented the typical "peritoneal" facies. The temperature was 102.4° F., the pulse 140, and the respirations 32. The abdomen was slightly distended and very rigid on both sides below the umbilicus. Above the umbilicus there was marked rigidity except in the substernal notch. The lower half of the abdomen was extremely tender, rather more so on the right. Occasional tinkling periastaltic sounds could be heard by auscultation of the abdomen. Vaginal examination showed tenderness in the vault of the vagina, but no masses or fixity of the uterus. The leukocyte count was 21,050 per cubic millimeter. By every clinical criterion the patient was hard hit and a very bad surgical risk.

It was decided to defer operation until improvement of the general and local condition occurred. She was placed on the treatment outlined immediately below. The pulse, temperature, and respiration began to fall almost immediately. The appearance improved. The rigidity of the abdominal muscles above the diaphragm began to relax the following day. The tenderness became more definitely localized in the right iliac fossa, though it continued present over the left lower abdomen. On the second day after admission a mass could be faintly outlined just internal to the right anterior superior spine of the ileum. At this time the pulse had improved greatly and ranged between 88 and 104. The temperature varied between 99.2° and 100.4° F. The respiration averaged 22. Three days later the mass was sharply defined. The general condition was satisfactory and operation was performed. The abscess was opened directly in the manner hereafter described, and was found to communicate with a large collection in the pelvis; the appendix was entirely gangrenous. Drainage was introduced as indicated. The pulse rose to 140 during operation. She was given 1000 c.c. of saline by hypodermoclysis. An ampule of pituitrin and $\frac{1}{4}$ grain morph. sulph. were injected hypodermically. She soon rallied and made an uneventful recovery.

This, in broad outline, is the usual course of this type of case when treated in this manner. Formerly by immediate operation a large percentage died promptly from fulminating toxemia and generalization of the peritoneal infection.

In such cases the pathologic condition is as follows: Diffuse peritonitis has been established. While the peritoneal inflammation may not be general, in the sense that every square inch is affected, including the upper abdominal and diaphragmatic areas, nevertheless the process is wide-spread, a large area is exposed to absorption of toxins, and the patient's resistance to infection is being strained to the utmost. The

area immediately about the appendix being the oldest seat of the infective process, has shown the most reaction, and the neighboring peritoneal surfaces are covered with fibrous exudate which largely prevents the further absorption of toxic material from this area by cofferdamming the lymphatics and capillaries and at the same time by cohesion of adjacent surfaces tend to shut off this area from the general cavity. In other words, this original focus is now contributing least to the toxemia evidenced by the condition of the patient. This toxemia is due to the extensive diffuse process going on independently of the infecting agent and at a distance from it. If by operation we could remove this diffuse process it would be justified, but experience has shown the futility of drainage or other measures in the treatment of diffused established peritonitis. Removal of the appendix will not stop it, because it no longer depends upon the appendix for its fuel. The same is true of drainage of the appendicular area. On the other hand, any active measures which do not do good assuredly do harm. Anesthesia, the manipulations necessary to even the quickest and most skilful operation, the opening of fresh areas to absorption are too often the means of enabling the advancing peritonitis to overcome the depleted resistance and the patient dies relieved of his appendix, but overpowered by the infection. To use an appropriate French expression "Elle est morte guerie"—she died cured. Much has been said of the relief of intra-abdominal tension in these cases. Theoretically, it is desirable. Practically, the area immediately drained benefits by the procedure, but it is a fatuous hope to relieve pus tension throughout the abdomen in diffuse peritonitis. It is the experienced who hesitate most in operating upon these cases. Yet the quick and skilful may take more liberties in the doubtful case than the inexpert. The practice of operating on a case "because it is evident that he is about to die without operation" is to be condemned. It is in just this condition that appropriate treatment will rescue a seemingly hopeless case and bring him into a state that operation can be performed with considerable hope of success. The vast majority of these cases have been improperly treated. They have had food and drink. Often, very often, they have been purged. They have been exhausted by pain and loss of sleep and they have had no fluid to maintain their blood-pressure, their metabolism, or their excretions, since the fluid unwisely given by mouth has failed of absorption in the stomach and upper intestines, and has been unable because of the paresis of the bowel to reach the large intestine where only it can be taken up in quantity. Many of these cases need only to be given a chance under proper conditions to turn the tables on the advancing peritonitis. The proper conditions are anatomic and physiologic rest plus fluid. The moribund cannot be saved by these measures. No more can they be saved by operation. The seemingly moribund often recover. The *rationale* of the measures to be adopted has been so often discussed in the last few years that it is superfluous to devote much space to the subject. They are so universally used after operation that their efficacy in this stage and the technic

of employment are well known. The purpose of this plea is to urge the recognition of a group of cases in which they are a life-saving preliminary to operation. The essential measures are:

(1) *Nothing* by mouth.
(2) The semisitting (Fowler's) position.
(3) Enteroclysis.
(4) Ice on the abdomen.
(5) Gastric lavage if indicated.

Careful nursing and attention to detail are essential. The position should be so arranged that it is comfortable and the patient should not be allowed to bend forward at the small of the back until his pelvis is parallel to the bed or nearly so, as is too often the case. This embarrasses respiration and defeats the object of the position, which is to secure inclination of the abdominal cavity and gravity drainage toward the pelvis. The so-called Fowler beds are too often a delusion. They might better be called procrustean beds, for they fit the average man and none else. The objectionable feature is not the back-rest, but the lower angle over which the knees are bent. In order to bring their legs over the angle short people are pulled so far forward that their backs are bent and the inclination of the pelvis is lost. A pillow secured beneath the buttocks by a sling extending to the head of the bed is much superior, unless, as chance may have it, the individual fits the bed.

To give enteroclysis properly requires understanding and care. Murphy's original gravity method is the best. Those of less experience will find the drop method more satisfactory. The patient should receive the maximum amount of fluid that he can absorb. Patients whose bodily need is great will take up an astonishing amount of fluid the first day; 6 or 8 liters are not an uncommon quantity. The great advantage of the Murphy method is that the patient regulates the amount he will take according to his physiologic demands, rather than receiving an arbitrary amount determined by the number of drops specified by the surgeon. We believe that physiologic salt solution is best at least for twenty-four hours, after which glucose solution (6 per cent.) may be used, and if acidosis exists it is rational to add enough sodium bicarbonate to make a 4 per cent. solution. In very toxic dehydrated cases an initial hypodermoclysis of salt solution is advisable. At least a liter should be given, and more if the tissues will readily take it up.

When enteroclysis is properly given it is rarely necessary to repeat hypodermoclysis. If, however, for any reason fluid in sufficient amount is not retained or absorbed by rectum, it should be given under the skin. During the acute stage of peritonitis at least 3 liters of fluid should be introduced daily by the most available means other than administration by mouth.

To allay anxiety and induce sleep, if necessary, small doses of morphin may be given. This drug must be used with great care in all abdominal cases, and if not specially indicated, it should not be used.

Either heat or cold may be applied to the abdomen. In the early feverish stage we have found that cold is most pleasing to the patient, and prefer it chiefly for that reason. It seems reasonable also that in this stage it is unwise to induce excessive hyperemia in the abdominal area already overstimulated by the acute inflammatory process. As subsidence begins hot fomentations are well borne and seem to aid in hastening resolution.

In the majority of cases under this treatment toxemia abates, distention subsides, the outlying areas of peritonitis clear up, tenderness and rigidity are restricted to the area of the appendix or abscess collections, and when it is evident that localization has occurred, operation may be performed. At the risk of repetition let us again specify that this plan of procedure is to be reserved for *late* cases, late in the sense that peritonitis is far advanced and rules the picture. There is none, we believe, who would not prefer to operate upon localized abscess, and it is upon the uniformity with which abscess formation can be induced by the above measures that this treatment is based.

Two important operative questions arise in connection with the more serious forms of appendicular peritonitis, namely, (1) drainage and (2) the method of dealing with localized abscess.

There have been no noteworthy modifications or additions to the technic of appendectomy since the appearance of Murphy's article. From a surgical standpoint the sole interest remains in the method of dealing with the chief complications of appendicitis, namely, peritonitis and abscess.

When the operation is performed in the stage of diffuse peritonitis, whatever the degree of the process, the appendix should be removed. When the process is recent, the amount of exudate slight, and the tissues not greatly affected by the inflammatory process the technic of operation may not differ in any way from simple appendectomy for the chronic or early acute case of this condition. The more advanced the process and the more serious the condition, the more imperative is it to operate quickly and with a minimum of trauma and disturbance of the intra-abdominal viscera. In all except the minority of cases, when the cecum and appendix are freely movable and may be delivered easily, it is important to use moist gauze pads to wall off the intestines from the site of the appendix. Enough gauze and only enough should be used to secure control. It is important, however, to use sufficient to accomplish the object and not to be diverted by the hue and cry raised in some quarters against intra-abdominal use of gauze. The artist in this field is known more easily by his use of gauze for this purpose than by any other step in the operation unless it be in the choice and arrangement of drainage. By means of pads properly placed the peritoneum is protected from trauma and contamination, the operation is expedited, and the steps made safe and certain. Adhesions are the result of pathologic processes and of unskilful operation rather than the insignificant trauma of gauze properly used. Ligature of the base of the appendix, removal without contamination, and hemostasis are the

important objects of this part of the operation. If it can be accomplished satisfactorily the stump of the appendix should be inverted with a purse-string suture or oversewn with Pagenstecher thread. The wall of the cecum may be too adherent or too friable to permit this step. If so, it may be omitted without hesitation.

After removal of the appendix the important question arises of the measures necessary to deal with the peritonitis. A small amount of slightly turbid exudate does not constitute an indication for drainage designed to carry off this fluid. Furthermore, the drainage, whatever variety be used, is a disadvantage, in that it delays healing and, more important still, is likely to generate adhesions between adjacent peritoneal surfaces that may give trouble at a later period.

It is now well known that the peritoneum can deal with a considerable amount of exudate, and it is appreciated that it is unwise to insist upon an active and extensive peritoneal toilet or to insert drainage for which there is no need. However, as the process goes on and the tissues become more inflamed and the exudate more highly infective and vicious in character, it becomes necessary in certain cases to modify the operation of appendectomy in certain details and to use drainage for certain definite indications. Naturally, these will be cases operated upon in the stage that makes decision difficult. In general, it is better to drain when in doubt. In this stage we ordinarily employ the fenestrated glass tube, and believe it to be superior to any other form of drainage. The objections to the glass tube have come from its misuse. The glass tube excites less reaction upon the peritoneal surfaces that come in contact with it and drains a larger amount of fluid than a rubber tube. It is never left *in situ* for more than twenty-four to thirty-six hours. During this time it is aspirated every one, two, or three hours, depending upon the amount of fluid that finds its way into the lumen. At every aspiration the tube is given a half-turn in order to free the fenestræ from tags of omentum or plugs of surface peritoneum that tend to obstruct and in some cases to anchor the tube. The character of the exudate is carefully observed. In these intermediate or doubtful cases it usually soon becomes clear straw color, and if upon smear or culture incubated a few hours no organisms are found, the tube may be withdrawn and the entire tract allowed to collapse. If, however, the fluid does not clear up and organisms persist, a small rubber tube is passed down the lumen of the glass tube which is withdrawn over it. In this manner a considerable number of cases may be afforded the additional safety of early drainage without the disadvantage of having a foreign body that must be left *in situ* for some days before removal can safely be begun. The cigarette drain cannot be so employed, since no information can be obtained as to the character of the drainage, and, moreover, the gauze tip of a cigarette drain is speedily cemented to the bottom of the tract, which makes early removal painful and dangerous. The rubber tube cannot be so satisfactorily handled, and its larger openings are often caught by the tissues. Another very valuable use of the glass tube is in determining the presence and character of fluid in

the pelvis. Many patients have developed pelvic abscesses, and not a few have perished because the surgeon neglected at the time of operation to ascertain the presence of an extensive exudate in the pelvis. This should always be done in case of doubt, and there usually is doubt in the acute stage or when peri-appendicular abscess exists. The tube should be passed down the posterolateral margin of the pelvis and aspirated with a syringe and tube. The decision for or against drainage will then be easily made.

It may be affirmed without hesitation that, properly used, the glass tube gives more information, drains more efficiently and with less trauma, and may be removed earlier than any other form of drainage. It must be said that the advantages cited for the glass tube are not often vital, and the rubber tube may be used as advocated by Murphy in all situations calling for tubular drainage. We do insist, however, that unfamiliarity with the glass tube is a frequent cause of failure to investigate the contents of the pelvis during the operation for appendicular peritonitis, an error which, if coupled with failure to provide drainage, may be followed by the gravest consequences.

In the more advanced cases of appendicular peritonitis even before localization and abscess formation has occurred it is common to find pus of a virulent character, as shown by its color, consistency, odor, and bacterial content. In these cases the appendix is usually adherent to its surroundings and after removal a bed of infected tissue remains whose viability is doubtful. In these cases drainage must be instituted for two reasons: (1) to wall off dangerous tissues from the general cavity, and (2) to convey infective exudates to the surface. It is obvious that the drain or drains must remain in place for a number of days. In these cases the best conduit to lead into a deeply placed area of infection is the rubber tube, and the best form of drainage to establish a tract shut off from the general cavity is the so-called cigarette drain. The cigarette drain carries off but little fluid through its central core of gauze which speedily becomes choked with coagulated exudate. It has the property of exciting adhesions to each other between the peritoneal surfaces which fall together about it without itself becoming adherent to them. In this respect it has a marked superiority over unprotected gauze drains, which soon become so densely adherent as to be water-tight. Gauze alone, therefore, as soon as its meshes become filled with gummy exudate, causes retention rather than drainage. The non-adherent impervious envelope of the cigarette drain permits abundant drainage along its periphery. Large cigarette drains of $\frac{1}{2}$ to 1 inch in diameter are very useful in creating a drainage tract. As many may be used as are made necessary by the extent of the process. The adhesions which are excited are not so dense and, therefore, not so difficult of absorption as those created by gauze, which causes a true granulation surface to form and leads to dense fibrous adhesions in the subsequent healing process. The management of the drain as introduced can be summed up by saying that it should be allowed to remain until it can be withdrawn without force. The cigarette drains attach

themselves to the bottom of the tract by the exposed gauze cores. These usually require a week or more before the attachment softens and permits withdrawal. The rubber tube also should be loosened at this time. At times the tube is anchored by tissues which have protruded through the fenestræ, and it is necessary to pull slowly and firmly until these processes are disengaged. The tube should then be shortened an inch or more daily until it is removed. It is far better to proceed slowly than too rapidly in the removal of drains. Foulness of the wound should not induce removal or active attempts at cleansing or deodorizing. The wound can soon be made clean when the drain has been removed. During the foul and sloughing stage antiseptic irrigations are helpful. Dakin's solution is very useful. Rough wiping and manipulations are harmful. For sinuses and clean wounds oily antiseptics are indicated, such as dichloramin-T in chlorcosane or balsum of Peru in castor oil.

Peri-appendicular Abscess.—When abscess formation has occurred, one of two courses remains open, either to open directly into the abscess if it abuts upon the overlying abdominal wall, or to open first into the free peritoneal cavity and wall off the uninfected area before attempting to deal with the abscess and the appendix which will usually be found embedded in the wall. Murphy threw the great weight of his opinion in favor of the latter method. He arrived at this decision rather early in his work in this field, being influenced, as he states, by 2 cases in which the abscess which he opened directly had ruptured into the pelvis, a condition which he did not at the time recognize, and led to disaster. We too have seen similar cases, but they did not lead to a change in the method of attacking this condition. It is not at all necessary to open into the free abdominal cavity in order to explore and drain the pelvis. In fact, this is an essential part of the operation for appendicular abscess whichever method of primary approach is used. We cannot but feel that if the pelvis had been explored and drained in the 2 cases presented by Murphy the outcome would have been different, and this could have been done through the incision employed to open the abscess. In order to comprehend the question as it now stands it must be understood that no one now advocates the so-called extraperitoneal operation of simple incision and drainage of the abscess. This is now of historic interest only. It is too well known that other collections of pus may exist, chiefly in the pelvis, and it is so well recognized that it is very desirable to remove the appendix if possible in order to prevent recurrence.

Moreover, it is not denied that the peritoneum can deal with the type of infection present as already shown by its ability to localize it in the form of an abscess, and it is granted that in certain cases it is necessary to open into the general cavity in order to deal with an abscess centrally placed or situated either high in the abdomen or low in the pelvis. In all these cases if excessive contamination is prevented and drainage is properly arranged, recovery is the rule. Still it is not proved that this is the method of choice in those numerous cases where

the peri-appendicular abscess is situated in the right iliac fossa and has for its anterolateral boundary the abdominal wall where it may be said to be pointing. In the vast majority of cases the collection is solitary. If not, the accessory pocket is in the pelvis or occasionally above, external to the colon. If one or more additional collections exist internally and above the brim of the pelvis, palpation will give evidence of it. Naturally, one would not attempt to deal with the latter condition except by an incision placed well anteriorly in order to give access to all suspected areas. However, in the case of the single abscess with or without pelvic or upward extension, which may be entered directly through the abdominal wall by an oblique incision just internal to the anterior superior spine, we believe this to be the operation of choice. The external oblique is divided in the direction of its fibers or nearly so. The internal oblique and transversalis are transected, but in the direction of the nerves. This leads to the thickened, inflammatory preperitoneal fat and peritoneum. By incising this the pus is evacuated and the cavity mopped grossly clean before any uninfected peritoneal surface is exposed. The appendix should then be sought and removed if practicable. This is almost always possible to one experienced in the operation. Occasionally it cannot be found without more trauma than is justifiable. It is better to leave the appendix for later removal than to jeopardize the recovery of the patient. This should not be necessary, however, in more than 2 to 5 per cent. of all cases.

The entire inner surface of the cavity should be carefully inspected for prolongation of the abscess tract. If there are any such in communication with the main abscess, a slight trickle of pus will often reveal their location. They are rarely present. The next step is to break through the lower boundary of the abscess with the gloved finger which is introduced into the pelvis. Following this and hugging the posterior wall of the pelvis a glass tube is introduced into the rectovesical pouch or culdesac of Douglas, as the case may be. Pus may reveal itself at once or become apparent only on aspiration by a syringe fitted with a rubber tube which is passed down the glass tube to its lower end. If pus is found, the glass tube may be allowed to remain, with the intention of substituting a rubber tube in the course of twenty-four hours after the abscess has been drained by aspiration, or a rubber tube may be substituted at once. If no pus is found it is safer to introduce a small rubber tube into the pelvis or a cigarette drain. The upper angle of the abscess cavity should be similarly investigated. The adhesions should be gently parted with the finger. If pus is present in the subhepatic space or in the right paracolic groove, it will then be revealed. When fluid or pus is found in this location the exploration must be carried to the extent of discovering whether or not the infective condition has involved the subdiaphragmatic area, and if so, drainage must be so arranged as to preclude the retention of pus in this location. This is the great preventive of subhepatic or subdiaphragmatic abscess which may complicate recovery if this step is omitted. The main abscess cavity is now packed loosely with gauze and the margins of the

incision partially approximated with several through-and-through sutures of silkworm-gut, which are used only to hold the pack in place and prevent undue gaping of the wound. A dressing and bandage is placed over all. The advantage of this operation is in the fact that peritoneal contamination is minimized and drainage is established at the most natural point of escape. No new areas of peritoneal surface are traumatized and caused to cohere as in the case of a drain introduced through the anterior incision, and lastly, by leaving the adhesions about the abscess substantially as they were, it is believed that absorption will occur more readily, postoperative obstruction be less likely, and the ultimate intra-abdominal condition become more nearly normal.

The after-management of the drain is substantially the same as that outlined above.

Purgatives.—There is no place for the purgative or aperient in the treatment of acute appendicitis either before or after operation. It is just as well to confess that it is only a few years since the profession as a whole endorsed the use of a purgative at the beginning of an attack of appendicitis on the ground that removal of irritating material from the bowel would favorably influence the course of the disease and promote recovery. This idea has now passed into history along with other follies of fallacious reasoning. We now know that this disease is an infection of the wall of the appendix and that it cannot be removed by a purge. Furthermore, we know that, like other acute inflammations, the infected appendix demands rest and protection rather than activity and stimulation. The distaste for food, the reflex spasm of the overlying muscle, and the inhibition of peristalsis are nature's attempts to maintain rest for the inflamed member.

Purgation with its violent induced peristalsis sets these conservative efforts at nought and increases the inflammation. Still more inadvisable is purgation when peritonitis has complicated the situation. If localization of the infection is desirable it is almost axiomatic that the stimulation of peristalsis is undesirable. Clinically, the worst cases are always those who have been actively purged. Next to delay in operation the purgative is the most prominent cause of death from appendicitis. It should never be used when acute appendicitis is suspected. A carefully given small enema may be useful in emptying the rectum in case of no recent movement.

After operation it was formerly the practice to give an aperient with the idea of securing early action of the bowels. This was based on faulty analogy. It is true that a resumption of function by the intestinal tract as shown by the passage of flatus and bowel contents is the most reliable sign of recovery. But this is true only because function is at first inhibited by trauma and disease and, again, this represents a conservative effort of nature. In simple clean conditions the early postoperative aperient is not dangerous, but it is doubtful if it does any good. It is certain that it does harm when peritonitis is present. It is our rule, therefore, to give no aperients after operation until convalescence is established, and not even then unless the condition demands

it. No attempt should be made to move the bowels during the state of active peritonitis until it is clear that localization and subsidence is beginning. A large enema or a too early administration of any enema is inadvisable. During the period of resolution of peritoneal inflammation the enema may do harm by exciting hyperperistalsis, thus causing exacerbation of inflammation. Also while paresis of the bowel exists the enema may not be returned and its presence increases discomfort and delays the recovery of normal tonus. A small enema of not to exceed 4 ounces of equal parts of glycerin and water may be given relatively early, but the large cleansing enema should be reserved until the time when it is apparent by the resumption of peristalsis and the passing of flatus that the bowel is able to take up its normal function.

CHAPTER XLIV

SURGERY OF THE GALL-BLADDER AND THE BILIARY DUCTS*

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Surgical conditions of the gall-bladder and biliary ducts at the present time include conditions in which heretofore surgical intervention has not been generally regarded as necessary. It is now known that various types of recurring cholecystitis without stones can be cured permanently only by removal of the gall-bladder. The appreciation of this fact, the development of diagnostic acumen, and the intensive study and classification of infections of the gall-bladder serve as a sound basis for the statement that surgical treatment is generally the most satisfactory method of dealing with many types of cholecystitis. It has further been shown that cholecystectomy rather than cholecystostomy is the best operation in the majority of cases of cholecystitis without stones, as only by cholecystectomy can permanency of results be assured the patient. The same statement may be made in regard to cholecystitis with stones, although the possibility of recurrence of symptoms if the gall-bladder is not removed in these cases is not so great as in the cases of infections without stones.

Surgeons who have had sufficient experience in the surgery of the gall-bladder and biliary ducts to realize these facts are convinced that cholecystectomy is the indicated operation in all infections of the gall-bladder, with or without stones, and is particularly indicated when pancreatitis is an associated lesion. Exceptions to this procedure are few, and practically confined to fulminating processes with local peritonitis, in which quick and efficient drainage gives the patient the surest and safest prospect of relief. Such relief, however, is usually temporary, and later removal of the gall-bladder may be an anticipated necessity. The whole question, therefore, may be aptly compared with appendicitis—if the appendix is definitely diseased it should be removed, and drainage without removal employed only as an emergency measure. Our experience in the clinic may be indicated by the fact that in 1918, 27 cholecystostomies and 839 cholecystectomies were performed.

The real problem now, however, is not that of cholecystostomy versus cholecystectomy, but the recognition clinically, and at operation, of chronic infection of the gall-bladder. An accurate clinical diagnosis of cholecystitis can be made, of course, in those cases (of which the so-called strawberry gall-bladder is the most characteristic ex-

* Supplementary to Chapter L, Vol. III, p. 966, and Chapter CXXVIII, Vol. VI, p. 600.

ample) in which the symptoms are so severe as to simulate those produced by stone. In many cases, however, a most careful analysis and interpretation of symptoms rather than special laboratory methods is at present practically the only method of reaching a correct diagnosis. *x*-Ray examinations are worse than useless, since a negative report may lead to delay—because of the lack of appreciation on the part of the physician and the surgeon that a negative *x*-ray means nothing in diseases of the gall-bladder—a delay which may result in the development of more serious trouble. In some cases cholecystitis can be suspected only in association with appendicitis, etc., and the judgment of the physician must determine whether sufficient symptoms are present to warrant exploration. Under such circumstances the actual diagnosis must be deferred until operation. At operation in such cases and, as a matter of fact, in all abdominal operations further difficulties in establishing a diagnosis are met.

Certain points are important in the recognition of cholecystitis at operation. As a rule, infection thickens and whitens the organ. Often, however, a blue gall-bladder has stones, but even without stones it may have serious changes in its mucosa due to infection. The lymphatic glands along the cystic, hepatic, and common ducts are always swollen in infections of the gall-bladder. They may be palpated with a finger through the foramen of Winslow and a thumb over the duct, and should be examined as frequently as opportunity offers in order that the surgeon may determine the size of the normal glands. A seriously infected gall-bladder cannot exist without evidence of the infection in the glands which drain it. These glands are also swollen in cases of papilloma of the gall-bladder, a rare condition also attributable to infection, which is possibly a factor in the etiology of cancer. In some instances, however, none of these findings are in evidence, and it is occasionally justifiable to remove what appears to be a normal gall-bladder on a definite clinical picture. The examination of the mucosa of the gall-bladder in such cases shows definite evidence of a chronic infection. The most important point, therefore, rests on the interpretation of the clinical symptoms.

Satisfactory exposure is of vital importance in removing the gall-bladder. Since the cystic and common ducts lie very close to the median line, the incision, whether for primary or secondary operation on the biliary tract, should be made rather close to the midline, usually not more than 1 or 1.5 inches to the outer side. Bevan's[1] incision is most useful. It begins at the ensiform cartilage, extends directly downward for 1.5 inches, then divides the upper half of the right rectus muscle on a line with the costal margin and about 1 inch from it. In certain cases in which a small high-lying liver with a deeply situated gall-bladder makes exposure of the pelvis of the gall-bladder and ducts difficult, Masson's[5] suggestion may be followed: He introduces a pack between the dome of the liver and the diaphragm; this not only immobilizes the liver against respiratory movements but also swings the gall-bladder very distinctly into a more accessible position for the sur-

geon. It should be remembered that the cystic duct has its origin above the lowest point on the posterior wall of the gall-bladder, so that

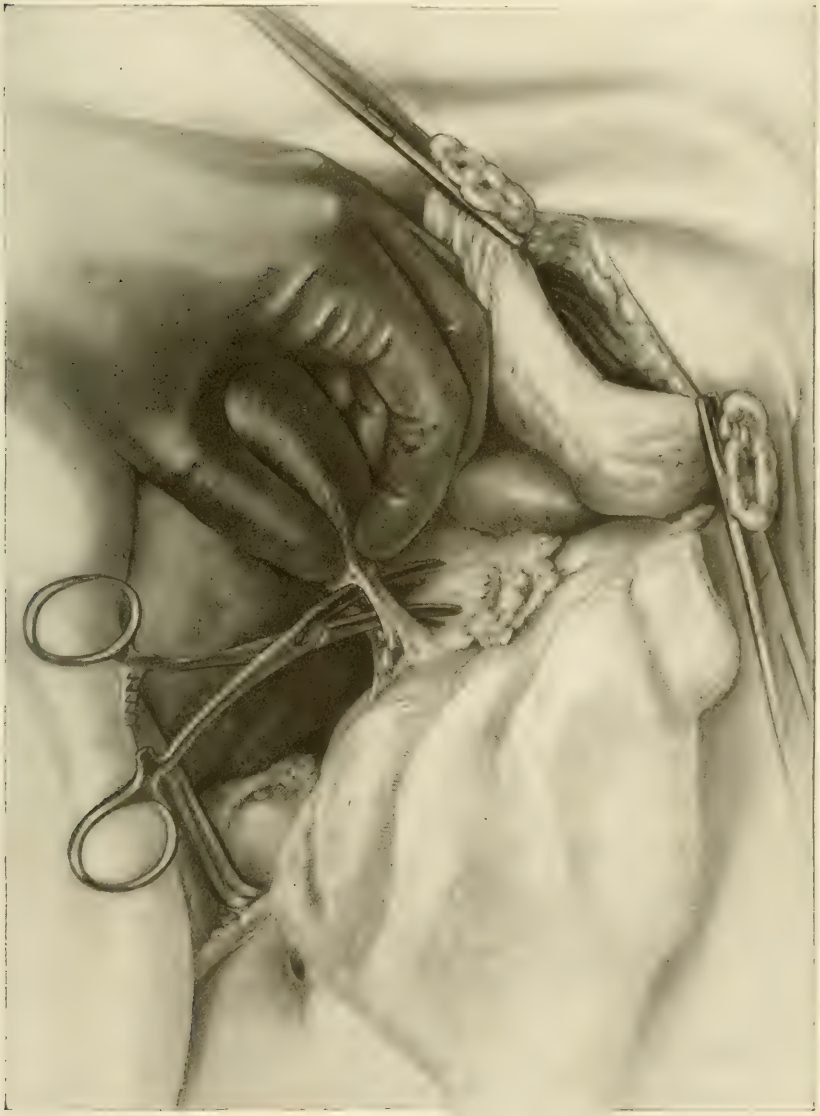

FIG. 368.—SUSPENSORY LIGAMENT DIVIDED.
Dissection of the cystic duct from the liver, common and hepatic ducts, the gall-bladder being held with the fingers.

the pelvis of the gall-bladder usually overlaps the cystic duct on its inferior and inner aspects. Quite frequently a little fold of peritoneum connects the pelvis of the gall-bladder with the gastrohepatic ligament

over the common duct, forming a small suspensory ligament. When this fold is present and associated with marked inflammation, many adhesions are often found in the little triangle thus formed. Since the fold lies in a line with the cavity of the gall-bladder, and, when markedly thickened, may be mistaken by the inexperienced operator for the cystic duct, the common or hepatic duct may be completely severed, or a section of it removed. To avoid this accident the pelvis of the gall-bladder should be dissected carefully from the triangle in order fully to expose the cystic duct, which may then be safely divided and ligated.

The cystic artery usually passes behind and not along the cystic duct to the gall-bladder. The relation of the artery to the duct is almost like that of a bowstring to a bow, as it is shorter than the duct and lies on a plane closer to the liver. It sometimes happens, therefore, that the duct is securely grasped without the artery being caught and, when the tissues are divided, the artery quickly retracts and bleeds freely. Hurried attempts to catch the artery with heavy rat-tooth forceps may result in serious injury to the great duct. When this artery is cut, it retracts into a pocket, but the forefinger, properly placed, will check the bleeding at once. A few mouse-tooth forceps can be caught in the tissues around the forefinger, forming a little basket, and by lifting on the forceps the finger can be removed and the artery caught with exactitude.

Judd's[3] method of carefully catching the cystic duct and artery, exposing them together and separating them from the notch of the liver while sealed in their connective tissue, may ordinarily be employed. It obviates any danger of injury to the common and hepatic ducts (Fig. 368).

Tumors of the Cystic Duct.—Benign tumors of the stump of the cystic duct may occur after cholecystectomy and cause obstruction of the common duct (Fig. 369). They cause typical symptoms of common duct obstruction, that is, colic, fever, chilly sensations, and exacerbations of jaundice.

Injuries to the Hepatic and Common Ducts.—Operations for the restoration of the common bile-duct are usually of a formidable nature, not only because of difficult technic but also because of the poor condition in which the patients usually come to the surgeon. As a result of the former operation and the continuation of local irritation adhesions are always extensive; they are supplied by an unusual number of thick-walled veins which tear readily and flood the field with blood or keep up a continuous oozing, thus adding to the difficulties of the operative procedure. All the bleeding vessels must be ligated, as they have a strong tendency to bleed after the operation even if they are quite small. It is especially important to tie the vessels in the subcutaneous tissues and skin; vessels in the muscle have less tendency to bleed after temporary clamping.[7]

Excision or Resection of an Obstructed Portion of the Common Duct with End-to-end Union.—The strictured portion of the duct is usually in the vicinity of the juncture of the cystic and com-

mon ducts and is from $\frac{1}{4}$ to $\frac{3}{4}$ inch in length. Such resections demand rather exact technic (Fig. 370). Adhesions are divided carefully and ligated instead of being separated. The duodenum and stomach will be found adherent to the gall-bladder notch, often completely overlying the common duct. This necessitates dissection of these structures until the margin of the gastrohepatic ligament can be identified. The foramen of Winslow is cleared and the second portion of the duodenum,

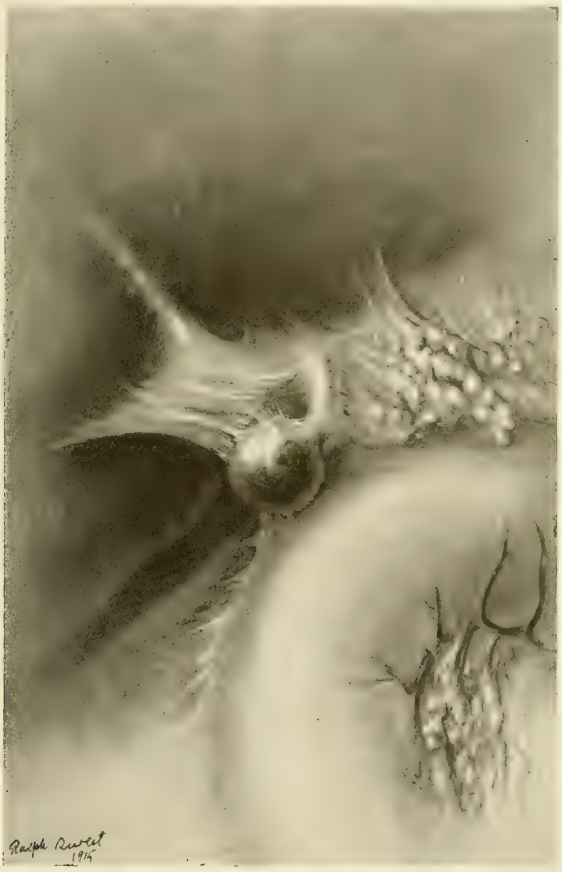

FIG. 369.—ADENOFIBROMA OF THE STUMP OF THE CYSTIC DUCT AFTER CHOLECYSTECTOMY, CAUSING COMMON-DUCT OBSTRUCTION.

if overlying the strictured area, is dissected from its position. There will be little difficulty in identifying the hepatic duct by tracing the source of the escaping bile either from a fistula, if there is one, or by an opening made in the dilated hepatic duct in the course of the dissection. It is surprising how easily the common duct may be found simply by carrying the dissection from the end of the hepatic duct directly through the strictured area along the margin of the gastrohepatic ligament. It might be expected that the distal end of the common duct would be

found contracted, but even after many months of complete obstruction it is normal in size. The stricture is dissected out until the ends of the hepatic and common ducts lie free; then several chromic catgut stay-sutures are introduced, catching the tissues behind the ends of the duct. When the sutures are tied they obliterate the posterior space and draw the hepatic and common ducts into position for suturing. A few catgut through-and-through sutures are placed so as to unite the duct ends posteriorly. The open end of the common duct is split along the anterior surface $\frac{1}{3}$ inch, as advised by C. H. Mayo.[6] The split in the free border of the common duct increases its caliber to a considerable extent; it is thus more readily coapted to the dilated hepatic duct. A **T** tube of appropriate size is now introduced, one arm extending

FIG. 370.—SHOWING END OF COMMON AND HEPATIC DUCTS SUTURED WITH THROUGH-AND-THROUGH CHROMIC CATGUT.

Dotted line shows where the end of the common duct is enlarged by short longitudinal incision.

about 1 inch into the hepatic duct to the primary division, and the other arm, if possible, extending through the entire length of the common duct until its free end passes into the duodenum (Fig. 371). The gap is closed about the **T** tube with chromic catgut sutures, the tube is fastened with an absorbable suture to the hepatic and common ducts, respectively, and the line of union covered by such omental and peritoneal tissues as may be available for the purpose. Normal salt solution is forced through the **T** tube with a syringe until it passes freely into the duodenum (McArthur[4]), and a few rubber-tissue drains are appropriately arranged. Introducing gauze in any form down to the line of union should be avoided if possible, as it tends to the formation of fistulæ. If necessary, a piece of rubber tubing may be placed in Morison's[8] pouch in the right renal area and carried out through a

stab-wound in the loin. As a rule, when the **T** tube is used for the reconstruction of the common duct it is not removed for about three weeks, when firm union has been established.

Strictured Area of the Common Duct Divulsed with Dilating Forceps.—For those cases in which the stricture, the result of ulceration, is in the pancreatic portion of the duct, it has been found satisfactory to open the common duct and pass a pair of dilating forceps

Fig. 371.—T-Tube in Place.
Duct ends sutured about it.

through the strictured area until it is completely divulsed. Strictures in this vicinity are usually of the character of a diaphragm, and will often pop like paper when forceps are passed through them into the duodenum. In the more difficult cases it is occasionally found necessary to open the duodenum and expose the papilla before undertaking divulsion. After divulsion a **T** tube with one arm sufficiently long to pass completely into the duodenum is placed in the duct.

Extensive Injuries to the Great Bile-duct Necessitating Union of the Hepatic Duct to the Duodenum.—In the more extensive injuries it may be necessary to suture the hepatic duct directly to the duodenum. In our experience in these cases the stomach and duodenum have been found closely adherent to the site of the injury. If care is used *not* to separate these adhesions too extensively, the duodenum may be so closely approximated to the dilated hepatic duct as to secure a two-row anastomosis without great difficulty, on the general principles of gastro-intestinal union. The omentum is carefully sutured around the anastomosis with fine chromic catgut (Fig. 372).

Union of the Common or Hepatic Duct to the Duodenum by Means of a Rubber Tube.—Technic of the Procedure.—The hepatic duct is united as well as possible by a mucomucous suture to an

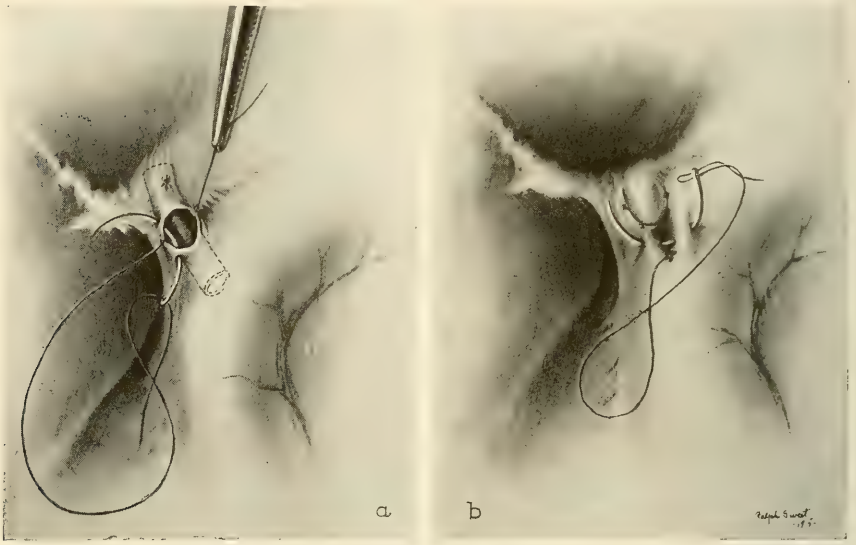

FIG. 372.—*a*, RUBBER TUBE IN PLACE AND FASTENED BY CHROMIC CATGUT SUTURE TO THE HEPATIC DUCT. ANTERIOR LAYER OF CHROMIC CATGUT CONTINUED. *b*, DUODENUM BEING SUTURED TO ENFOLD ANASTOMOSIS, THE AREA LATER TO BE COVERED BY OMENTUM.

opening made into the duodenum over a rubber tube sutured in position. The tube extends into the hepatic duct to the primary division and about 1 inch into the duodenum. The suture is continued in such a manner that at least some portion of the new canal may be lined with mucous membrane. The line of union is, of course, not bile-tight, but when it is surrounded with omentum it does not seem to leak into the peritoneal cavity. After the absorption of the holding sutures the rubber tube readily passes into the intestinal tract.

Direct Union of the Common Duct to the Duodenum.—We have used this method a number of times following resection of the common duct for cancer and once following partial gastrectomy for cancer of the pyloric end of the stomach. After removing the involved portion of the common duct the distal end is tied, the stump is covered

with peritoneum, and the proximal end is united to the duodenum after the method of Coffey.[2] The method is applicable in primary operations when the hepatic end of the duct is easily accessible: in secondary operations there are, as a rule, so many adhesions that the duct cannot be sufficiently mobilized to accomplish its direct union to the duodenum.

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CHAPTER XLV

TESTS FOR RENAL FUNCTIONAL EFFICIENCY IN SURGICAL CONDITIONS *

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During the last few years a vast amount of work has been devoted by many investigators to the development of renal functional testing. The promising results obtained from employing any one of a variety of salts, dyes, and drugs as an index of renal functional capacity has been a great stimulus to these investigations. The substance selected is introduced into the body orally, subcutaneously, or intravenously, and the efficiency of renal function is gaged by the promptness of appearance or rate of elimination of the substance in the urine. Further impetus has also been afforded by the development in the last few years of a great number of microchemical methods for the quantitative estimation of the various organic and inorganic constituents of the body fluids. These methods, which for the most part require only a few cubic centimeters of fluid for the estimations, have made possible the quantitative analysis of the blood and body fluids in pathologic conditions, and have thus not only greatly extended our knowledge of the disturbances in the intermediary metabolism in disease, but have given us methods of investigation which are becoming of greater and greater value in the diagnosis of individual cases. As it is especially the disturbances in renal function which lead to striking alterations in the chemical composition of the blood, these microchemical methods have increased considerably the number of the available renal functional tests.

The renal functional tests now available fall into four groups: 1. Tests based upon the character of the elimination in the urine of certain foreign substances introduced into the body for the purpose of testing the renal function. These substances include methylene-blue, indigocarmin, phenolsulphonephthalein, potassium iodid, and lactose. Phloridzin also may be placed in this group, although the substance eliminated in the urine in this test is glucose.

2. Tests based upon the character of the elimination in the urine of the normal urinary constituents, especially water, urea, total nitrogen, and chlorids under certain specified conditions of intake and régime.

3. Tests based upon disturbances in the composition of the blood, as indicated by its freezing-point, its total refractive index or the refractive index of certain constituent fractions, its content of total non-

* Supplementary to Chapter LV, Vol. IV, p. 168, and Chapter CXXXII, Vol. VI, p. 634.

protein nitrogen, or of one of the component nitrogenous substances (urea, uric acid, ammonium salts, amino-nitrogen, creatin, and creatinin), its content of chlorids.

4. Quotients or indices calculated according to certain formulas from the urea or chlorid concentration and output in the urine and the urea or chlorid concentration in the blood.

Of these many tests some are of greater value and of wider applicability than others. Those selected for routine use in renal functional diagnosis will vary somewhat with the individual worker.

First Group.—Phenolsulphonephthalein Test.—Of the tests in the first group, the most recent, the phenolsulphonephthalein or, for short, the phthalein test, has deservedly become the most popular. It has proved both the simplest and the most reliable of the group, and is without detrimental effects upon the patient. The technic of this test and its significance are discussed in Volume VI, page 634. A few supplementary statements may be made here, however, with regard to it.

In the original technic, as described by Rowntree and Geraghty, catheterization was always employed, a catheter being introduced just before the injection of the drug in order to determine the interval between the injection and the first appearance of the drug in the urine. In cases in which no retention was found, the catheter was then removed and the urine voided one hour and, again, two hours after the time of appearance of the drug in the urine.

In selected cases catheterization may be dispensed with provided it is certain that there is no retention of urine.

For the estimation of the amount of the drug eliminated in the urine several simple colorimeters have been devised. These make unnecessary such expensive instruments as the Dubosq, and have the further advantage that they are much simpler to use and to read. Among these may be mentioned the Rowntree and Geraghty modification of the Königsburg-Autenrieth colorimeter and the Dunning colorimeter. (Both may be obtained from Hynson, Wescott Co., Baltimore, Md., or their agents.)

Concerning the significance of variations in the phthalein excretion, the following may be noted: In passive congestion of the kidney the phthalein excretion is usually reduced and, in cases of marked cardiac decompensation, it may only be a trace. It exhibits, however, a rapid rise upon improvement in the circulatory condition.

In acute nephritis the phthalein excretion may be only moderately reduced or may be zero. Probably no prognostic importance can be attached to the degree of its reduction in this condition, for a zero phthalein has been noted in cases of acute nephritis with subsequent complete recovery.

In chronic nephritis the reduction in the phthalein is closely proportional to the impairment in renal function, and the greatest reduction is usually observed in those cases in which uremia is imminent or present. It is in this group of cases that the phthalein test is of the greatest diagnostic and prognostic importance.

In prostatic cases, or in any case in which the impairment of renal function is secondary to obstruction in the lower urinary tract, the phthalein output may be greatly improved by a period of adequate catheter drainage associated with free administration of water, perhaps with urinary antiseptics. In such cases, where the phthalein is distinctly lowered, a preliminary period of treatment should always precede operation if delay is permissible, and the operation be undertaken only when the phthalein output has been raised to the highest point to which it can be brought by treatment.

In arteriosclerotic hypertension the phthalein elimination is usually normal or but slightly impaired, or it may be excessively high, and this fact is of importance in that it enables us to distinguish readily between the hypertension of chronic nephritis with marked impairment of renal function and danger of uremia, and the hypertension of arteriosclerosis, with but little, if any, impairment of renal function so long as the myocardium remains adequate.

In applying the phthalein test to the study of the function of each kidney separately, instead of collecting the urine from each side through the ureteral catheter for a period of an hour, the phthalein may be injected intravenously and the separate urines be collected for only fifteen minutes instead of an hour. During this time each normal kidney should excrete at least 15 per cent. When one kidney is badly diseased and its phthalein excretion almost zero, the other kidney may compensate, so that for the fifteen minutes its phthalein excretion may be 30 per cent. This method of studying the functional capacity of each kidney separately enables one not only to compare each kidney with its fellow, as may also be done by the estimation of the urinary output and urea excretion from each ureter, but also gives an absolute figure which serves as a criterion of the absolute functional capacity of each kidney, and hence has a distinct advantage over the other methods just mentioned. Inasmuch as ureteral catheterization may lead to a reflex inhibition of renal excretion, and hence to a lowered phthalein output from the catheterized ureters, it should be the rule to precede such an examination by an ordinary phthalein test done in the usual way a day or two in advance. If the phthalein elimination from the two kidneys obtained through ureteral catheterization is considerably lower than the total phthalein recovered in the preliminary test without ureteral catheterization, the difference is to be attributed to reflex inhibition of renal function from the ureteral catheterization rather than to any loss of renal functional capacity. Certain limitations and uses of the phthalein test from the surgeon's standpoint are noted by Braasch and Thomas[1] as follows:

In cases of renal calculus a marked reduction of phthalein from the affected side is not necessarily a sign of sufficient destruction of renal parenchyma to warrant nephrectomy, for, in some instances following removal of the calculi, the phthalein on that side returns to normal. With tumor in the renal region unilateral reduction of the phthalein has aided in making the diagnosis of renal neoplasm when the urine was

entirely normal. In most cases of essential hematuria the phthalein elimination is normal. Therefore, unilateral hematuria associated with unilateral reduction of the phthalein suggests renal tuberculosis, calculus, renal neoplasm, or chronic pyelonephritis; on the other hand, a normal phthalein does not exclude any of these conditions.

When, in early renal tuberculosis, tubercle bacilli have been found in the urine and cystoscopic examination fails to determine the affected side, this may sometimes be indicated by a difference in the phthalein output on the two sides. In renal tuberculosis, as a rule, if the total phthalein elimination exceeds 40 per cent. in two hours, the condition is still unilateral, but exceptions to this rule occur.

Perinephric abscess may give a marked unilateral reduction in phthalein when the urine is quite normal.

Miller and Cabot[2] have used the phthalein test to study renal function after operation. They find, as a rule, a diminished output after operations, especially after laparotomy and operations for cancer; in general, the diminution in the phthalein excretion is proportional to the amount of ether used and the length of the operation. Return to the preoperative level occurs in from about twenty-four to forty-eight hours. Exceptionally there is no postoperative diminution, or there may be, curiously, even an increased output. On the other hand, in rare cases the diminution amounts to total suppression of the phthalein output. Shock causes a marked decrease in the output. Postoperative albuminuria is not proportional to the phthalein reduction.

Of the other functional tests in this group, all have proved of less value than the phthalein test except, possibly, for certain specific purposes. The iodid, phloridzin, and methylene-blue tests have been practically universally discarded; the lactose test advanced by Schlayer and Hedinger as a test specific for the glomerular function of the kidney has not been established as truly an index of the functional capacity of this particular portion of the renal excretory apparatus, and hence its chief justification ceases to exist. It is a very troublesome test to carry out, and the injection of the lactose is not rarely followed by a severe chill. The lactose test is very sensitive to slight disturbances of the renal circulation, being sometimes considerably impaired by very slight grades of passive congestion. It affords no aid, contrary to the expectations, in the later stages of an acute nephritis in predicting the persistance of glomerular involvement or the likelihood of a chronic glomerulonephritis developing as a sequel of the acute attack. The lactose test has, indeed, nothing to recommend it for diagnostic purposes when a test so far superior as is the phthalein is available.

The **indigocarmin test** does, however, serve a purpose for the estimation of the function of the two kidneys separately, inasmuch as the dye can be seen through the cystoscope as it emerges from each ureter. The lapse of time between the injection of the dye and the time of its appearance from either ureter serves as the gage of the functional capacity of each kidney separately, and can be observed without the need of ureteral catheterization.

The technic of this test is as follows: A 4 per cent. solution of the dye in water is made and sterilized. The cystoscope is introduced and the ureteral orifices watched; 20 c.c. of the solution is then injected into the muscles, usually of the gluteal region, and the time of injection noted. Watching the ureteral orifices, the dye should appear as a greenish-blue stream coming from each orifice. It appears in normal individuals in from ten to fifteen minutes after the injection. Excretion is usually complete in twenty-four hours, but the greater portion escapes in twelve hours. The color of the dye in the urine does not lend itself well to colorimetric estimation. In this respect it resembles methylene-blue. Purulent urine decolorizes indigocarmin. It is estimated that not more than 25 per cent. of the amount injected finds its way through the kidneys. The fate of the balance is unknown.

As a rule the indigocarmin elimination is delayed in the same conditions in which the phthalein elimination is reduced. Occasionally, however, one of these tests is much more disturbed than the other. Unfortunately, not enough studies have as yet been made in which both of these tests have been used to enable us to interpret the significance of the occasional discrepancies between them.

Second Group.—Concerning the second group of tests, those based upon the elimination of water, of total nitrogen or urea and of chlorids in the urine, little need be added to the discussion already presented in the article on Renal Functional Testing in Volume IV. The study of renal function by testing the kidneys' capacity for prompt water elimination, the experimental polyuria test of Albarran, is there described.

Emphasis may well be laid upon the significance of variation in the urinary specific gravity as an evidence of renal efficiency, and upon the significance of a specific gravity above 1020 as a mark of kidney functional capacity of fair order. When the renal functional capacity becomes impaired the kidney loses its power of excreting urine of high specific gravity, and eventually becomes incapable also of excreting exceedingly dilute urine; hence the specific gravity tends more and more to become fixed at about 1.011 to 1.013. Under such conditions a demand upon the kidney for increased elimination of solids is met by a polyuria without alteration in the percentile composition of the urine or in the urinary specific gravity. The kidney has lost its capacity to concentrate the urine and there exists a persistent hyposthenuria. While the excretion of urine of high specific gravity is evidence of fair preservation of renal functional capacity, the excretion of urine of a specific gravity of 1.011 to 1.013 may be merely incidental to the elimination of a considerable amount of water from free water drinking or from the ridding of the body of collections of edema fluid, and can only be taken as evidence of impaired renal function when it persists on a dry régime under conditions which in a normal individual should lead to excretion of urine of high specific gravity.

Urea Excretion.—As already noted in Volume IV, the rate of urea elimination or its concentration in the urine is without significance

except when considered with respect to the nitrogenous intake of the individual. The urea excreting function of the kidney may, however, be tested by some such method as von Monakow's. In this method the patient is placed upon a standard weighed diet of constant protein content for several days, estimating the daily output of urea or total nitrogen. When the daily nitrogenous excretion becomes approximately constant (usually three to five days) 10 gm. of urea are added to the standard diet, and, still continuing the standard diet, note is taken of the number of days required for the complete elimination of this added amount of urea. Normally the extra urea should be completely eliminated in from twenty-four to forty-eight hours. When renal excretory function is impaired the elimination may not be completed for four or five days or a week. Such a study requires all the scrupulous accuracy in regulation of intake and collection of urine that is demanded in a metabolic experiment, and this over a period of about ten days. [It is accordingly a method, as a rule, not available except in occasional cases or in clinics especially devoted to metabolic work.]

Chlorid excretion may be studied in the same manner as urea, but with the same objections and difficulties, rendering the method inapplicable, as a rule, for surgical diagnosis.

Recently Hedinger and Schlayer, and subsequently, in this country, Mosenthal have introduced the use of a so-called *renal test-meal*, which consists of a standard mixed diet, which is to be taken for three days. On the third day the urine is collected in two-hourly periods from 8 A. M. to 8 P. M., and in a single period from 8 P. M. to 8 A. M. These seven specimens of urine are analyzed for quantity, specific gravity, urea, and sodium chlorid content. The efficiency of the kidneys is estimated from the character of the variations in composition that occur in these specimens of urine in response to the meals. The study of renal function by this method probably gives information concerning the renal function of as great value as, or even greater than, that derived from such tests as von Monakow's, in which a certain quantity of urea or chlorid is added to an ordinary diet and the number of days required for its complete elimination noted. The study by test-meal has the further advantage of requiring but three days for its completion instead of some ten days, as is necessary for the von Monakow test. Mosenthal's meal[3] is as follows:

"All food to be salt free from the diet kitchen. Salt for each meal will be furnished in weighed amounts. One capsule of salt, containing 2.3 gm. of sodium chlorid, is furnished for each meal. The salt which is not consumed is returned to the laboratory, where it is weighed or measured after meals and charted. Allow no food or fluid of any kind except at meal times. Note any mishaps or irregularities that occur in giving the diet or collecting the specimens.

Breakfast, 8 A. M.:
Boiled oatmeal, 100 grams.
Sugar, 1 to 2 teaspoonfuls.
Milk, 30 c.c.
Two slices of bread (30 grams each).
Butter, 20 grams.
Coffee, 160 c.c.
Sugar, 1 teaspoonful } 200 c.c.
Milk, 40 c.c.
Milk, 200 c.c.
Water, 200 c.c.

Dinner, 12 M.:
Meat soup, 180 c.c.
Beefsteak, 100 grams.
Potato (baked, mashed, or boiled), 130 grams.
Green vegetables, as desired.
Two slices of bread (30 grams each).
Butter, 20 grams.
Tea, 180 c.c.
Sugar, 1 teaspoonful } 200 c.c.
Milk, 20 c.c.
Water, 250 c.c.
Pudding (tapioca or rice), 110 grams.

Supper, 5 P. M.:
Two eggs cooked in any style.
Two slices of bread (30 grams each).
Butter, 20 grams.
Tea, 180 c.c.
Sugar, 1 teaspoonful } 200 c.c.
Milk, 20 c.c.
Fruit (stewed or fresh), 1 portion.
Water, 300 c.c.

8 A. M.: No food or fluid is to be given during the night or until 8 o'clock the next morning (after voiding), when the regular diet is resumed.

Patient is to empty bladder at 8 A. M. and at the end of each period as indicated below. The specimens are to be collected for the following periods in properly labeled bottles:

8 to 10 A. M.; 10 A. M. to 12 M.; 12 M. to 2 P. M.; 2 to 4 P. M.; 4 to 6 P. M.; 6 to 8 P. M.; 8 P. M. to 8 A. M.

The above dietary contains approximately 13.4 grams of nitrogen, 8.5 grams of salt, 1760 c.c. of fluid, and a considerable quantity of purin material in the meat, soup, tea, and coffee. All of these purins act as diuretics, and it is on the mode of excretory response to such stimuli that this method of study of renal function depends. Mosenthal points out that since the food as found in most households suffices to carry out these tests, and the procedure is not a complicated one, it need not be confined to hospitals.

The most important characteristics of the urine in normal individuals on this nephritic test diet are, according to Mosenthal:

"1. Variations in the specific gravity of the urine in the different specimens (usually ten points or more).

"2. The balance between the daily output and intake of salt, nitrogen, and fluid. This should be approximately equal.

"3. A night urine high in specific gravity (at least 1.016, but usually 1.018 or higher), high in its percentage of nitrogen (about 1 per cent.),

and small in amount (400 c.c. or less), regardless of the quantity of fluid ingested or the amount of urine voided during the day."

When kidney function becomes impaired the changes that occur may be formulated as follows, although this order of events will not be followed in every case:

1. Nocturnal polyuria (over 400 c.c.).
2. Tendency to total polyuria (the volume of urine equals or surpasses the quantity of liquids ingested).
3. Fixation of specific gravity, gradually becoming more intense, until it is absolute and the specimens only show a maximum variation of .001 to .002. In the earlier stages the specific gravity may be fixed at a higher level than later.
4. Fixation of the two-hourly quantities of urine eliminated; that is, the usual polyuric response to meals is absent.
5. The quantity of night urine may diminish to within normal limits. Such night urines, however, are characterized by a low specific gravity and a low percentage of nitrogen.
6. A retention of both salt and nitrogen, which may become very marked.

Such functional pictures, however, are not confined to nephritis. They are found regularly in many other conditions: pyelitis, cystitis, hypertrophied prostate, marked anemia, pyelonephritis, polycystic kidney, and diabetes insipidus. The cause of diminished renal function, it is clear, must be sought for in many directions—the urinary passages, the blood, or the kidney itself. Prognosis and therapy will depend largely on the cause of the fundamental impairment and not on its degree. A divergence between the degree of functional renal involvement and the intensity of the signs and symptoms of nephritis is frequently found, and accentuates the lack of parallelism that there may be between functional and anatomic lesion.

"In chronic diffuse (parenchymatous) nephritis the condition of renal function is characterized by its variability. In these instances the results of the test-meal have proved to be extremely valuable in giving an idea of the status of salt, nitrogen, and water excretion, besides the picture of renal efficiency as a whole. The findings in myocardial insufficiency vary according to the activity of the heart. Distinct differences are found with myocardial decompensation between the period of accumulation of edema, the period of eliminating edema, and subsequently, when cardiac compensation is again fully established. It requires some time before the kidney resumes its normal activity. The intervening period is indicated by a tendency to a low, fixed specific gravity and a nocturnal polyuria. During the period of full myocardial decompensation the results of kidney activity are very characteristic; the specific gravity is markedly fixed at the level of about 1.020, the salt output is diminished, that of nitrogen is high in marked contrast to the salt, and there is oliguria. When chronic nephritis and cardiac decompensation coexist, as they so often do in hypertensive nephritis, the urine may exhibit the characteristics due to either

lesion. The determining factor is probably to be found in the chronic nephritis which may or may not be so far advanced as to present an unchanging barrier to the influence of renal congestion."

Whether this method of renal functional study possesses any advantage over the phenolsulphonephthalein test, or over the determination of nitrogen or chlorid retention in the blood by the analysis of the blood for these substances, is a question that cannot yet be answered.

These latter methods demand of the patient merely the drawing of the necessary blood from the vein, a process evidently less incommoding and certainly less time consuming than the institution of a weighed diet and the accurate collection of the urine at stated periods. In a patient very ill, perhaps on the verge of uremia, the renal test-meal outlined by Mosenthal could not be given without considerable danger and would have to be materially reduced, both as to its salt and protein content. This fact impairs somewhat the value of this method of study.

Third Group.—Of the third group of tests, those based upon alterations in the composition of blood, quite a number have been recently developed. Cryoscopy of the blood has already been discussed in Volume IV. The refractive index of the serum, either the total refractive index or the refractive index of the various protein fractions of the serum, while of value in researches upon the pathologic physiology of the kidney, has less practical value as a diagnostic test of renal function than have the other methods about to be mentioned. The microchemical methods for the estimation of the total non-protein nitrogen of the blood or of the various component nitrogenous fractions are the methods of this group which have probably the greatest clinical value. These methods include those for the estimation of the total non-protein nitrogen, the urea, creatin, creatinin, and uric acid, and, less important as an evidence of the functional condition of the kidney, of the amino-nitrogen of the blood.

All of these nitrogenous fractions except the amino-nitrogen tend to be increased in the blood in any case of serious impairment of renal function and may be raised to from eight to twenty times the normal value. Such increase is especially common in those cases in which uremia is present or impending.

Normal figures for these nitrogenous fractions are as follows:

	Milligrams of substance per 100 c.c. of blood.	Milligrams of N. per 100 c.c. of blood.
Total non-protein nitrogen	.....	22 –30
Urea	25 –40	12 –19
Uric acid	0.9– 3	0.3– 1
Creatin	2.1– 6.4	0.6– 1.8
Creatinin	1 – 1.4	0.4– 0.5
Amino-nitrogen	.....	3 – 8
Ammonia nitrogen	.....	0.2– 0.5

Of the various constituents of the non-protein nitrogen the urea is quantitatively the most important, and of the new micro-methods for the estimation of these various nitrogenous fractions Marshall's method

for the estimation of the blood urea, as modified and simplified by Van Slyke and Cullen,[4] is both the simplest and the most useful. The general nature of this method is as follows:

One c.c. of whole oxalated blood* is required for each test and the test always should be made in duplicate. To the 1 c.c. of blood placed in a suitable test-tube properly stoppered and connected by tubing with a receiving tube or flask there is added a buffer phosphate solution and a solution of urease (which is readily prepared from a preparation on the market†). The tube is stood in a water-bath at 40° C. for twenty minutes to favor the conversion of urea into ammonium salts by the urease. The contents of the tube are then made alkaline with sodium carbonate, and the ammonia which is thus freed is drawn by an air current in twenty minutes from the tube to a receiving tube or flask containing a known amount of N/50 sulphuric acid diluted. The receiving solution is then titrated with N/50 sodium hydrate and the combined amount of ammonia and urea in the blood calculated. The air current is provided by a pump or aspirator. The entire process can be completed in forty-five minutes and requires comparatively simple apparatus and few reagents. For the detailed technic the original article should be consulted.

In the severest cases of nephritis the blood urea may rise from 100 to 300 mg. per 100 c.c. of blood. The level of blood urea is determined in part not only by the efficiency of the renal function but also in part by the amount of the protein intake in the diet or by the rate of protein destruction in the body. In the normal person the blood urea can be increased to about 60 mg. per 100 c.c. by the administration of a large amount of urea by mouth. When the kidney is nephritic and the elimination of urea is impaired a much greater increase in the blood urea may be induced by the administration of urea or of a high protein diet or by any toxic or febrile condition causing rapid tissue katabolism. Therefore, in the interpretation of blood urea as an index of renal function, the patient's régime and general condition must be taken into account. It is also desirable for the same reason that the blood for examination be drawn before the morning meal or four hours after a very light meal.

The blood urea as well as the other non-protein nitrogenous fractions tend to be increased in the same conditions in which the phthalein excretion is impaired, so that it is unnecessary to detail these again at length. The blood urea estimation and the phthalein test are, therefore, to a considerable extent interchangeable methods of gaging the renal function, and either may be used as confirmatory of the other. The phthalein test is less influenced by the character of the patient's diet or by the rate of protein destruction in the body. On the other hand, the blood urea is somewhat less readily influenced by passive congestion of the kidney than is the phthalein elimination. Rapid

* Blood drawn into a vessel containing a few crystals of potassium or sodium oxalate, added to prevent coagulation.

† Arlco-urease, manufactured by the Arlington Chemical Company, Yonkers, New York.

changes in the efficiency of the renal function are reflected more quickly in the phthalein test than in the level of the blood urea.

Concerning the significance of changes in the level of the plasma chlorids, for the estimation of which McLean and Van Slyke[5] have recently published a method that requires only a few cubic centimeters of blood, little can as yet be said. Wolferth,[6] using this method in a study of a series of cases of nephritics, found an increase in the plasma chlorids in most cases of nephritis. Sometimes, however, a low level of the plasma chlorids was found associated with very poor capacity for excreting chlorids added to the diet. This was noted usually in individuals who had been for some time on a very low chlorid intake. Occasionally the reverse of this relation was observed. For the present at least the study of the plasma chlorid must be considered as a means of research into renal physiology and not as a clinical test of the state of renal function.

Fourth Group.—It is established that neither the rate of urea excretion, the concentration of urea in the urine, nor the level of urea in the blood can be taken alone and individually as a measure of renal functional efficiency with respect to urea excretion. The attempt has been made, therefore, to determine the normal quantitative relation between these and certain other associated factors, divergence from which can be considered an index of impaired renal efficiency.

Ambard[7] and his associates, from investigations on the dog and in man, concluded that, other factors being constant, the excretion rate of urea normally increases as the square of the blood urea concentration and inversely as the square root of the concentration of urea in the urine. That is, that doubling the concentration of urea in the blood excites four times the rate of urea excretion and that increasing the rate of urine excretion fourfold increases the rate of urea excretion about one and a half times (1.59). These relations he expressed in the following formula:

$$\frac{U^2}{D \times \frac{70}{W} \times \frac{\sqrt{C}}{25}} = K.$$

U = Grams of urea per liter of blood.
D = Grams of urea excreted in twenty-four hours (or a twenty-four-hour excretion calculated from the excretion during a shorter period; *e. g.*, seventy-two minutes).
W = Weight of the individual in kilos.
C = Grams of urea per liter of urine.
K = Quotient, the index of renal functional capacity.

This formula was inverted and otherwise slightly modified by McLean[8] to give a quotient or index which in normal cases will average about 100, and depression of which results from impairment of renal functional capacity. McLean's formula is as follows:

$$\frac{D \sqrt{C} \times 8.96}{W \times U^2} = \text{Index.}$$

The letters have the same significance as in the original formula.

Using Ambard's formula the normal quotient is from 0.8 to 1, and impairment of renal function causes an increase of the figure. With McLean's formula the normal figure is 80 to 100, or often considerably higher, even 250 or 300, and impairment of renal function lowers the quotient or index.

The usual method for determining the separate factors involved in these calculations is as follows: The patient, on an empty stomach, is given 300 c.c. of water to drink. Half an hour later the bladder is completely emptied voluntarily, if possible, or by catheterization if necessary. Seventy-two minutes later the bladder is emptied again and the quantity and urea content of the urine determined. At exactly the middle of the seventy-two-minute period blood is taken from a vein and used for blood urea determination.

The validity of Ambard's laws are by no means established. Marshall and Davis[9] concluded that in dogs receiving plenty of water urea excretion increases in simple direct proportion to the increase in blood urea concentration and not as the square of the latter. Addis[10] and his associates and Van Slyke, Stillman and Austin[11] have reached the same conclusion both for dog and man. The two latter groups of workers have further concluded that the concentration of urea in the urine cannot be introduced into the formula in the manner employed by Ambard. Van Slyke, Stillman and Austin have shown that both in dog and man the rate of urine volume excretion is a more useful factor in the formula than the concentration of urea in the urine. The relation which they find to hold for man and dog is the following:

$$\frac{D}{U\sqrt{V \times W}} = K.$$

The letters have the same significance as in the formulas given above, except V, which signifies urine volume excretion, expressed in liters per diem as calculated from the short period of urine collection. The use of V in this formula must be further qualified by the condition that only increased rate of urine volume excretion up to a certain limit increases the rate of urea excretion (D). This limit they call the "augmentation limit" and find that it varies in different individuals, but lies usually for normal man between the rates of 3 and 5 liters per diem. Beyond this augmentation limit D varies directly as U, unaffected by further increase in the rate of urine volume excretion (V). The value of K for normal man lies between 4.5 and 10.5, with an expected normal variation in any individual of 2, or approximately 25 per cent. of the value of K.

In selecting among the renal functional tests those that are to be employed in any given instance, the choice will be influenced by the purpose of the investigator. One of two ends will be primarily in view. He may desire information as to the degree of impairment in renal function in order to gage the likelihood that a uremia may impend, or to anticipate the probability of an acute renal insufficiency following some operative procedure. Or, on the other hand, he may wish

to study as thoroughly as possible every phase of renal function in order to form the most complete picture possible of the precise functional condition of the kidney. This latter type of investigation belongs rather to the field of clinical research in renal physiology and pathology appropriate to the medical or surgical clinic, and to this end everyone of the functional tests has its individual value and no two completely duplicate each other. The former purpose is, however, that which more frequently concerns the surgeon, and to this end, in addition to the ordinary examination of the urine for quantity, specific gravity, reaction, albumin, sugar, casts, epithelium and blood-cells, and to the blood-pressure estimation, the most valuable tests are the phthalein test, occasionally the indigocarmin test, and the estimation of the blood urea nitrogen considered with respect to régime, general condition, and perhaps to the rate of urea excretion in the urine in a seventy-two-minute period of urinary collection, as employed by McLean.

Acidosis.—The recent introduction of a number of valuable methods, simple enough for clinical use, for the detection of the condition known as acidosis and for the estimation of its severity has excited an increased interest in this subject. Before entering upon a discussion of these, a few words may be said about the nature of the acid-base equilibrium in the blood. Owing to its peculiar composition the blood possesses remarkable powers of absorbing acids and alkalis, with little change in its own reaction. This capacity is most essential to the organism, for it makes possible the transfer of acids or alkalis from the point of origin or absorption to the eliminating organs without significant change in the reaction of the transporting fluids. This constancy of reaction in the blood so essential to life is secured by the presence, as L. J. Henderson[12] has shown, of buffer substances. Of these, the most important are the bicarbonates, hemoglobin, and the proteins, with phosphates playing a minor part.

Acidosis may be defined as an abnormal diminution in the amount of these buffer substances in the blood. A direct effect of this alteration in the composition of the blood is a reduction in the CO_2 carrying capacity of each unit of circulating blood for any given difference of CO_2 tension. The resulting accumulation of CO_2 in the tissues, however, stimulates the respiratory center and leads to the maintenance of an increased ventilation of the pulmonary alveoli and a lower carbon dioxid concentration in the alveolar air. This, by increasing the difference of CO_2 tension between the tissues of the body and the alveolar air, compensates for the altered composition of the blood, and establishes a new equilibrium in which the CO_2 tension of the tissues is higher and the CO_2 tension of the alveolar air lower, while the carrying capacity of the blood for CO_2 for any given difference of CO_2 tension is less. The increased pulmonary ventilation is the most constant secondary effect of acidosis. In mild acidosis it can be detected only by the measurement of the carbon dioxid content of the alveolar air which will be found below normal; in severe acidosis the deepened respiration at an increased rate constitutes the most characteristic feature of the clinical

symptom-complex. The kidneys, if their activity is not impaired, excrete an increased quantity of acids and the urine can be rendered alkaline only by the administration of a larger dose of soda or other alkali than is required in the normal individual. The ammonia of the urine may be abnormally high due to the formation of this substance instead of urea in the body; this serves in the body as a base and spares its fixed bases. When the acidosis arises from the production of the ketone acids, beta-oxybutyric, diacetic, and acetone, the presence of the two latter may be detected by qualitative tests in the urine, or all three may be estimated by quantitative methods. The amount of these substances in the blood may also be determined. In its mildest forms acidosis can be detected only by use of some special test or one of the laboratory methods about to be mentioned. The milder grades of acidosis occur in a variety of pathologic conditions apparently without great detriment to the patient. The severer grade is a very serious, usually fatal, condition.

Acidosis of milder or severer grade has been found to occur in the following conditions among others: in starvation; on a protein-fat diet, even though calorically adequate if without carbohydrate; in diabetes mellitus, nephritis and cardiorenal disease; in surgical anesthesia; in surgical shock; in eclampsia; in severe sepsis; in methyl alcohol poisoning; and, in children, in a variety of conditions and much more frequently than in adults; for example, it may occur during almost any infection in childhood, during the severe diarrheas of children, and in the condition known as cyclic vomiting.

While frequently observed in all of these conditions, acidosis rarely reaches the severe grade except in a few of these conditions, especially in diabetes mellitus and in some of the acidoses of childhood. This condition of severe acidosis exhibits a symptom-complex of which the most characteristic feature is the peculiar hyperpnea without cyanosis. The respiration is much increased. Vomiting and headache are usually prominent symptoms. In diabetic acidosis, acetone and diacetic acid are to be found in the urine and there is an aromatic odor to the breath.

The acid bodies responsible for acidosis are not the same in all cases. In starvation, on a protein-fat diet, and in diabetes mellitus they are chiefly the ketone bodies. The same is probably true of many of the severe acidoses of childhood. On the other hand, in nephritis and in the severe diarrheas of children Marriott and Howland[13] have found evidence that acid phosphates are largely responsible for the condition. In methyl alcohol poisoning unidentified organic acids have been shown by Van Slyke and Palmer[14] to be concerned.

For the recognition of acidosis we have available a number of methods. In the first place, the condition may be suspected on the basis of the symptom-complex of acid intoxication just described, with its peculiar respiration, vomiting, and headache. To rest the diagnosis on this basis, alone, however, will lead to frequent error, for further investigation by special methods has repeatedly failed to reveal acidosis in cases at first so diagnosed on symptoms alone. When, however,

acetone and diacetic acid are found in the urine in association with the characteristic symptom-complex, the diagnosis is more secure. On the other hand, it must be remembered that acetone and diacetic acid appear in the urine in many of the mildest forms of acidosis, cases that are in no sense to be considered serious, and in which the slight acidosis has no bearing on the prognosis. This is especially frequent in children. For example, Holt has found acetonuria in 70 per cent. of the pneumonias of children. There are many forms of acidosis, on the other hand, which, arising from other acids than the ketone acids, cause no acetone or diacetic acid to appear in the urine. For the recognition of these and for the more accurate gaging of all forms of acidosis it is very desirable that one of the newer methods now available be used. The most reliable is the Van Slyke[15] method for determining the carbonate content of the blood. About 5 c.c. of blood taken from a vein is employed in this method, although it can be carried out with somewhat less, and the technic requires about the same degree of familiarity with laboratory methods as does the determination of blood urea.

Next to this in value is the estimation of the carbon dioxid content of the alveolar air. A very simple method for this has been devised by Marriott[16] and recently published, and Howland and Marriott have recently adapted it for use with infants and young children. It can be carried out in a few minutes, but there is opportunity for error from faulty methods of breathing on the part of the patient.

The third test (Sellards[17]) is the determination of the amount of soda that must be given a patient to render the urine alkaline to litmus—4 grams suffice in the normal individual. Two, three, or four times this amount, or sometimes much more, depending upon the grade of the acidosis, will be required in a case of acidosis. If there be no cystitis to alter the reaction of the urine between the kidney and the test-tube, this simple test is of considerable value.

After ether anesthesia Austin and Jonas[18] have found a moderate depression of the CO_2 capacity of the plasma (Van Slyke method), indicating a slight acidosis. This depression is proportional to the duration of the anesthesia, is present and probably maximal at the close of the anesthesia, and apparently remains little altered for at least five hours. In all the cases studied by them, however, the acidosis was of very slight grade. Similar findings have been reported by Morriss[19] and by Caldwell and Cleveland.[20]

A most important contribution to the relation of acidosis to surgery is furnished in the work of Cannon[21] upon acidosis in shock, hemorrhage, and gas infection. Cannon and his co-workers demonstrated a parallelism between the fall of blood-pressure and the degree of acidosis in these conditions. Cannon attributes this acidosis to the stagnation of the circulation in the peripheral vessels. Diminished blood flow, by impairing the oxidative processes and bringing about only partial oxidations, would be expected to give rise to the formation of acid bodies. Gaskell, Bayliss, and Hooker have all presented evidence that acids tend to induce

local vasodilatation, and Cannon is inclined to consider that the peripheral capillary dilatation, which he observed in shock and which he considers a fundamental factor in the impaired circulation, tends to be maintained and augmented by the acidosis.

Restoration of the normal bicarbonate content of the blood by the injection of carbonate solutions intravenously has been accomplished in individuals suffering from shock without significant improvement in the circulation. It remains to be determined, therefore, in what degree acidosis is an important factor in shock and to what extent it is merely an incident.

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CHAPTER XLVI

SURGERY OF THE KIDNEY *

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The opinion expressed in my chapter in Vol. VI, on the Surgery of the Kidney, in regard to the importance of renal functional tests and blood examinations has been strengthened by the clinical experience and experiments made during the intervening period.

The entire question of serious operations upon the kidney depends upon the establishment of renal function by means of the phenolsulphonephthalein test and the test of the chemistry of the blood. An adequate excretion may be present with neither kidney performing its full function. It has been experimentally established in animals that one-fourth of a normal kidney will maintain function sufficient for life to continue. The removal of one kidney, however, may so reduce the excretion that it is incompatible with life. Unfortunately, ureteral catheterization and cryoscopy will fail at times to determine beyond peradventure of doubt that a kidney left after nephrectomy will maintain function sufficient to sustain life.[1]

The injection of substances impervious to the *x*-ray into the pelvis of the kidney has also made considerable advances. Although, as previously stated, the procedure is not without some risk, it is often indicated to determine to a nicety not only the condition of the pelvis, but in some instances the actual site of the kidney itself. By this means abnormalities of the pelvis or of the ureter, or of both may be clearly shown. The presence of a dilatation or of a divided pelvis may be recognized, and what is of most importance is that tumors of the kidney which are as yet impalpable may be demonstrated by the deformity caused from their impinging on the pelvic lumen.

In a chronic pyelitis which has resisted all internal medication, it is possible to give relief by the direct application of one of the silver salts through the urethral catheter. It is a procedure, however, which should be left as a last resort, since not a few deaths have resulted from distention of the renal pelvis, made with a view to securing radiograms.

So eminent an authority as Braasch[2] believes that pyelography should never be used when the diagnosis can be made without it. It should never be attempted in the old and feeble or if the condition of the other kidney is not entirely normal. In all cases the catheter should be allowed to remain in the ureter for fifteen or twenty minutes after the radiogram has been taken, in order that the pelvis of the kidney may drain thoroughly.

* Supplementary to Chapter LVI, Vol. IV, p. 183, and Chapter CXXXIII, Vol. VI, p. 639.

Whether thorium, presented by Burns,[3] or some of the silver salts be used and permitted to remain in the pelvis, they have resulted in diffuse abscesses throughout the cortex, with evidences of acute pyelitis. When these unfortunate conditions result, urethral catheterization with irrigation must be resorted to, and if relief is not obtained, immediate nephrectomy may become necessary. Excessive distention of the pelvis must always be guarded against, whether the injection be made for pyelography or therapeutically. Hoffman reports a case of a girl fifteen years of age with an infected hydronephrosis. Four days after the injection of a 4 per cent. collargal solution the patient died of peritonitis. Collargol was found in the uriniferous tubules and in the cortex. The danger of overdistention is very great. In a case of Wossidlo,[4] a few days after such an examination, the pelvis was found filled with blood and the kidney itself contained numerous infarcts, throughout which were masses of collargol in the intertubal connective tissue. Both he and Eisendrath found that as soon as the amount of collargol inserted exceeds the pelvic capacity it infiltrates into the interstitial connective space between the tubules, even though no lesion of the kidney itself is demonstrable. When very large quantities are used it passes through the walls of the pelvis.

Since the syringe has been abandoned for the gravity method of injection, and the importance of using a very small ureteral catheter, so that any excess fluid may flow back through it without pressure, has been recognized, it is probable that the dangers have been greatly lessened.

Recurrence After Removal of Stones from the Kidney.—With a large number of operations performed for stone in the kidney in the four decades since the operation was first performed, it is now possible to consider the question of recurrences. The fact that cases are not rare in which small calculi are passed from time to time makes it certain that recurrences must occasionally present themselves in persons operated on for kidney stone. Recently we saw a man who was operated upon twelve years ago, and now has a very small calculus in the right ureter and another in the bladder. The radiogram shows them to be no larger than a fair-sized pin-head. There are no symptoms, either urinary or otherwise, and the shadows may be of phleboliths. Every patient after operation for stone should be *x*-rayed before leaving the hospital.

The frequency of recurrences is shown by the figures of Cabot,[5] according to whom among 66 patients operated upon for renal stone at the Massachusetts General Hospital, recurrence of stone was found on re-examination in 49 per cent. One of the most frequent causes of recurrence of stone has been the conservation of a badly damaged kidney, which was of little functional value. Therefore nephrectomy is probably the best procedure to adopt when a calculous kidney is badly damaged. The removal of a stone through too small an incision in the pelvis or the cortex is to be condemned, since small fragments may be left and act as nuclei for the development of other stones.

In the Mayo Clinic, of 88 patients operated upon who returned for

re-examination, 14 per cent. had recurrences. From my own experience I believe that these percentages are entirely too large, since patients who are entirely well do not return for re-examination. Furthermore, the appearance of shadows after operation may be extrarenal as demonstrable by cystoscopic or operative examinations. Although the operation on the kidney may fail to remove all of the stones present, and thus account for some seeming recurrences after operation, the presence of stones thus left is rarely the cause of a continuance of symptoms. The continuance of symptoms may be due to the slow subsidence of the infection which originally produced the stone, and the recurrence of symptoms may readily be ascribed either to reinfection or to some scar tissue in the kidney itself or the tissues without.

While a great dependence must be placed on the *x*-ray for the recognition of stone in the urinary tract, its fallibility, as stated in the original article, is becoming more and more recognized. The mistakes are of two types, as Braasch properly states: (1) By error in interpretation, and (2) failure to show the shadow of the stone. Interpretation of the shadow picture without adequate clinical and particularly cystoscopic data must, of necessity, be inaccurate, and operations based on the evidence of a shadow alone, according to Braasch, is not good surgery. In the large series of cases reported it was found 78 per cent. were either in the pelvis or at the ureteropelvic juncture, while 21 per cent. were cortical.

In this connection there may be a brief consideration of the association of stone in the kidney and malignancy. Since I[6] reported a case of this nature, not a few cases have been reported in the literature, and of these Martin and Mertz[7] made a collection and analysis. There were 108 cases all told, mostly reported by foreign writers. This associated condition was found to be five times as common in males as in females, and the symptoms due to stone had existed for nineteen years, whereas the period in those due to malignancy was approximately only five months. Epithelial neoplasms were found to be the variety commonly associated with stone and they were oftenest found in the pelvis. Sarcoma was the rarest of all. It is certainly evident that the primary lesion in the vast majority of cases was a stone which produced a proliferation of the pelvic epithelium by irritation.

Renal Tuberculosis.—Although I hold that tuberculosis of the kidney is a surgical condition as long as the condition is unilateral and there are no similar grave lesions elsewhere, and that immediate nephrectomy is the operation absolutely indicated, the question occasionally arises whether the disease is ever curable without operation. Climatic treatment and rest have long been known to be of service in inoperable cases. I have a case in which by reason of bilateral involvement of the kidney and bladder an operation could not be performed. A change of climate, with absolute rest for six months, quickly changed conditions. This was twelve years ago and the patient continues well.

Dillingham[8] has reported 50 cases of tuberculosis of the kidney and bladder that were clinically cured without operation; not that he pre-

fers this method, but in all of these cases there was either a bilateral involvement precluding surgical measures or else operation was flatly refused by the patient. The treatment he used consists in giving an injection of $\frac{1}{75000}$ mg. of tuberculin twice a week, which is increased in amount so gradually that there is never a local or general reaction. In cases complicated by pulmonary infections the initial dose was reduced to $\frac{1}{75000}$ mg. In addition to these injections irrigations of the bladder with weak silver nitrate solution (1 : 50,000) are given. The strength of this solution is gradually increased, the surgeon being careful not to cause irritation either from the strength of the solution or the rapidity of its injection.

Although the low mortality rate of nephrectomy for tuberculosis has long been recognized, it is of interest to know whether or not the patient has been permanently cured of the disease. The fact that tuberculosis of the kidney without involvement of the ureter and bladder is quite rare renders the probability of permanent recovery a matter of great concern. Nephrectomy removes only the focus of the infection in the urinary tract, but this usually suffices to strengthen its resistance against the invading infection and thereby helps to cure the remaining lesion.

The immediate mortality obtained by Lower[9] in 100 consecutive nephrectomies for various lesions was less than 1 per cent. Lower has made an interesting report on the end-results of nephrectomies performed in Cleveland. There were 87 cases with 2 deaths within four weeks, and before the patients left the hospital. Of a report showing a later mortality, 2 patients died of tuberculous peritonitis, 4 of pulmonary disease, while the cause of death in the remaining 4 is not known. The longest interval between operation and death was seven years, the patient dying of pulmonary tuberculosis at the age of thirty-seven. From 45 of the patients replying to a questionnaire, in 48 per cent. of the cases having painful and frequent micturition before operation, some bladder symptoms persisted. In each of these cases the bladder trouble had extended over a long period before operation. In 9 per cent. no definite improvement in the bladder symptoms followed operation; 20 per cent. of the cases operated upon reported themselves in perfect health.

It appears from the reports that most cases, in which the symptoms persisted for more than a year before operation, do not experience much improvement during the first year after operation. After this time the improvement is gradual but definite, as shown by the fact that there were only 5 patients who considered themselves absolutely unimproved in this respect.

To shorten the time for making inoculation diagnosis of renal tuberculosis Morton[10] describes a method which is based upon the observation of Murphy and Ellis.[11] White mice, which had been exposed to x-rays, were made materially more susceptible to bovine tuberculosis than normal animals. Morton's experience shows that the same thing holds good for the human strain of tubercle bacilli in the guinea-pig. By resorting to the use of guinea-pigs thus exposed a diagnosis can be

made in from eight to ten days, whereas by the use of ordinary animals it requires from five to seven weeks.

Nephrectomy in bilateral tuberculosis is, of course, rarely advisable. Nevertheless, in over 200 nephrectomies at Zuckerkandl's Vienna clinic,[12] the operation was done five times despite a definite diagnosis of bilateral involvement. In each of the 5 cases the removed kidney was a pus sac. One patient died soon after operation, 4 were alive at the time of the report, but in only 1 had two years elapsed since operation. But in every case there was an immediate and marked improvement in the general condition.

Hematuria.—The importance of hematuria as a symptom of the disease in the urinary tract maintains its position, for there is no single urinary symptom that brings a patient to a physician quicker than hematuria. Some idea as to the relative frequency of the cause of hematuria may be gained from the clinical study of Kretschmer.[13] He studied 238 consecutive cases of hematuria, including only those in which the blood was apparent to the naked eye. An accurate diagnosis could be made in only 200 of the cases. The lesion was traced to the kidney in 74 cases, to the bladder in 86, to the ureter in males in 10, and to the ureter in females in 2 cases. The most frequent single cause was tumor in the bladder. Tuberculosis was next in frequency, while there followed in order tumors of the kidney and calculi. In regard to the term "essential hematuria," he believes that it is simply a scientific method of acknowledging our diagnostic limitations.

In this connection I[14] have reported a most interesting case of profuse hematuria with tumor in the left upper quadrant. The cystoscopic examination showed the blood coming direct from the left ureter with a rhythmic expulsion. The diagnosis of cystic sarcoma of the left kidney was made. The operation failed to reveal anything wrong with the kidney, but disclosed a very large pancreatic cyst, which by pressure on the renal vein caused the hematuria. The operation was followed within two days by complete cessation of the hematuria.

Polycystic Kidney.—Recent investigations have shown that both bilateral and unilateral polycystic disease is much more common than was formerly supposed. Barnett[15] collected 251 cases, of which 101 were unilateral. Although the disease is unquestionably congenital, it may develop at an earlier period in one kidney than in the other, and therefore in its earlier stages the kidney may be so little enlarged as to be considered normal in size.

Rovsing's operation doubtless relieves the pain and causes an improvement in renal function. The operation consists of free exposure of the kidney through a lumbar incision, and puncture of as many cysts as feasible, always avoiding damage to healthy tissue. As the cysts near the surface are punctured the kidney can gradually be drawn into the wound, and deeper ones made accessible for puncture. Only one kidney at a time should be operated upon.

Up to May, 1916 Braasch[16] collected 41 cases from the Mayo Clinic, the average age of the patients being forty-six years. Pain was not

often found severe, although he found that interference with drainage by a blood-clot or stones not infrequently gives rise to colicky attacks. It is important to note that hematuria occurred in 16 of the 41 cases. Since renal insufficiency in this affection resembles that of chronic nephritis, congenital disease should always be suspected when there is impaired kidney function in the young. In 31 of the 41 cases a renal tumor was found before operation. The Rovsing operation was performed ten times, while in 14 a nephrectomy was done.

Nephropexy.—The indications laid down for this operation in the former volumes have been more firmly fixed with the passing of time. The many suspension operations for displaced organs which were advocated a decade ago have to a large extent gone into "innocuous desuetude." The loose kidney is not to be made the subject of operation unless there is frequent pain in the renal region, more or less marked Dietl's crises, and some urinary disturbance, as revealed by the ureteral catheterization, demonstrating a hydronephrosis of at least 6 or 7 c.c. *x*-Ray examination should be a routine procedure before operation. Whether or not the thorium injection is to be used may be a question because of its inherent danger. That the operation of nephropexy is becoming less and less frequently performed is shown by the statistics of Clark and Block,[17] who have made a follow-up investigation of the 50 cases that have been operated upon in fifteen years. From 1900 to 1905 there were 1385 ward admissions, among which 18 nephropexies were performed. Between 1905 and 1910 there were 1765 admissions, with only 15 such operations. From 1910 to 1915 there were 2422 admissions, with only 17 such operations, thus showing the steady diminution in the percentage of elective cases. Divided into five-year periods they were enabled to get full data of 36 cases; the percentage of cures is about the same in all the three groups. They count on curing about 70 per cent. provided the cases have been carefully selected.

As to the operation itself Bartlett[18] has made a new suggestion. He does not perform a suspension operation, but by splitting the fat capsule and inverting it as much as is done in the bottle operation for hydrocele he gets a large pad of fat below the kidney, which supports the organ. All of the fat from the posterior abdominal wall having been previously removed, the surface of the kidney is placed in close relation to the muscles, so that firm adhesions may be formed.

Congenital Anomalies and Ectopia of the Kidney.—A kidney normal in size and in regard to pelvis, normally placed, is best fitted for drainage. *Per contra* one that is abnormally placed with or without a division of the pelvis is less easily drained, and, as has been shown, is less able to withstand infection. Suppuration and stone are much more likely to develop in it than in the normal viscus. The frequency with which such anomalies occur has been well shown by Bugbee and Losee,[19] who report no less than 23 cases. With the increase of laparotomies a congenitally fixed position of a kidney in an abnormal place has been found to occur with greater frequency, although the condition must still be considered comparatively rare. Autopsies in large patho-

logic institutes have shown that the presence of kidney in the pelvis occurs about once in 1500 subjects.

Strater[20] reported on 63 operations in 67 cases, of which 48 were performed on the kidney proper. At the Mayo Clinic[21] there were 19 cases of pelvic kidney. In 9 of them operations were done because of pathologic conditions in the misplaced kidney. In the remaining 10 cases the condition was discovered during the course of some other operation or in making a routine examination of the kidney. In none of these 10 cases were there any symptoms.

The blood-supply of the ectopic kidney comes from lower down than in a normal kidney, either from just above the bifurcation or from the common iliac or from the midsacral artery. The ureter, of course, is shorter than normal. The most common location of such a kidney is entirely within the pelvis proper, behind the uterus or resting on the promontory of the sacrum. Because of the vascular pedicle it is, as a

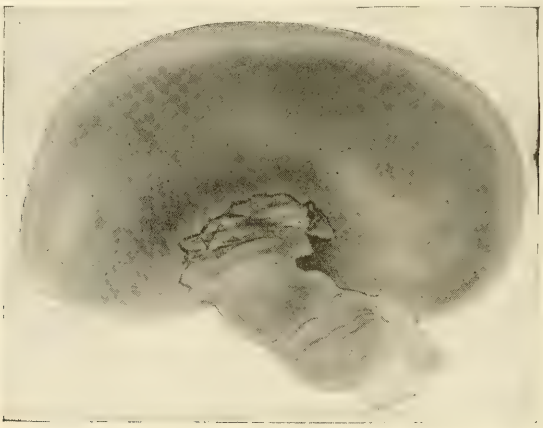

Fig. 373.—Ectopic Kidney with Twisted Pedicle.

rule, firmly fixed, and by reason of the shortness of the vessels and of the ureter it cannot be raised much by operation. With this congenital anomaly there are not infrequent malformations of the genitalia.

Although it would appear from autopsies that malposition of the kidney is as common in men as in women, it is oftener recognized in women because the symptoms, if there are any, simulate disease of the uterus or tubes or ovaries. To mistake one for an ovarian cyst or tubal disease would not be difficult. So far as treatment is concerned, with the kidney functioning normally it should be left untouched in its position. When symptoms are produced indicating pathologic changes in the ectopic organ the causes are the same as for similar conditions in the normally placed kidney.

Ectopic Kidney with Twisted Pedicle.[22]—When the pelvic kidney is not fixed there is a possibility of a twisted pedicle, with an infarct fatal to the kidney. On November 22, 1919 there entered the Jewish Hospital a child of twelve, with the diagnosis of appendicitis of forty-

eight hours' duration. There was a leukocytosis of 9000, slight pain in the abdomen. Temperature which had been 102° F. had dropped to normal. Urine normal. The operation, November 24, 1919, revealed a slightly inflamed appendix with peritoneal varices and a twisted ectopic right kidney. The twist involved the fallopian tube also. It was from left to right, three and one-half rotations. The ureter was very short. The artery apparently came off from the iliac near the bifurcation of the aorta. There was no ovary present on the right side. There were no urinary symptoms whatever. As soon as it was discovered that recovery of the kidney was out of the question it was removed, but not until the left kidney had been palpated and found to be of normal size. So far as I know this is a unique case of twisted ectopic kidney.

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CHAPTER XLVII

SURGERY OF THE BLADDER AND URETERS*

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DIAGNOSIS OF VESICAL AFFECTIONS

Formerly much reliance was placed on the "stone-searcher" for determining the presence or absence of stone in the bladder.

Both because of the proved inadequacy of this instrument for resolving this question—its evidence having proved misleading in many instances—and because of the much greater efficiency of the cystoscope, the searcher has passed almost into "innocuous desuetude," being utilized occasionally merely as a preliminary test. One must determine not only as to the presence or absence of a stone but also the size,

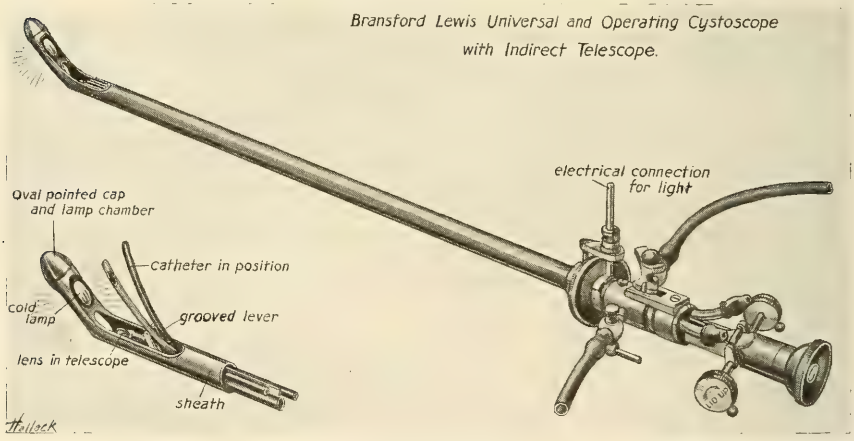

Fig. 374.—Bransford Lewis Universal and Operating Cystoscope with Indirect Catheterizing Telescope.

number, and character of such foreign bodies. These questions are readily determined by the cystoscope; also others of equal import, such as the presence of complicating factors, diverticulum, tumor, prostatic hypertrophy, contracture at the vesical neck, etc.

The same also is true of various forms of the segregator; they have accompanied the "searcher," having been eclipsed by the performances of the cystoscope in respect to diagnosis and therapy, including both vesical and ureteral conditions.

* Supplementary to Chapter LVII, Vol. IV, p. 272, and Chapter CXXXIV, Vol. VI, p. 666.

While the recent war situation was a serious impediment to the development and construction of surgical appliances—expert workmen being diverted in large numbers into the manufacture of munitions—there has been, nevertheless, some improvement noted in regard to simplifying the construction and amplifying the capabilities of cystoscopic apparatus. The ureter itself has proved a responsive field of attack for the cystoscope and its several accessory appliances, such as were described in Vol. IV of this work, and made for the author by the Wappler Company of New York. In this cystoscope (Figs. 374, 375) the one sheath and two telescopes (direct and indirect) provide all the needs of cystoscopy in the broadest sense. It is unnecessary to have different instruments for covering the various requirements for observation, double ureteral catheterization, and cystoscopic operating.

This one instrument provides for the following:

1. Free irrigation, either before or during cystoscopic manipulations.
2. Observation by direct view.
3. Observation by indirect view.

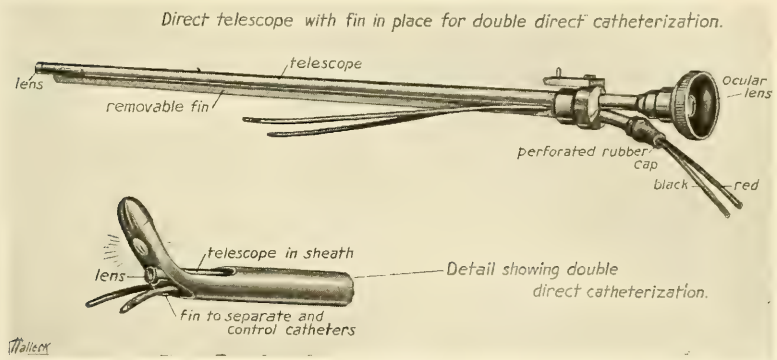

Fig. 375.—Telescope for Direct Double Catheterization, Universal and Operating Cystoscope.

4. Double ureteral catheterization by direct method up to Size 7.
5. Double ureteral catheterization by indirect method up to Size 7.
6. The transmission of single ureteral catheters up to Size 9, French, by either the direct or indirect telescope.
7. The transmission of the several operating instruments, forceps, scissors, ureteral knife, ureteral dilators; graduated ureteral bougies; prostatic electric incisor and all of the various forms of high-frequency electrodes. If desirable it would permit the use of a wire loop, but this is seldom used since the advent of high-frequency fulguration.

A radium applicator has been devised (Fig. 376) which is arranged to carry the radium element in a platinum capsule, and protected by a proper rubber cap (it is essential that this be black, not red, rubber). It is introduced into the bladder either through the cystoscope above described or, in favorable cases, is introduced through the urethra independently of the cystoscope.

The curve of the silver wire shaft serves to direct the radium toward

the tumor. If the cystoscope is used it is withdrawn immediately afterward, leaving the radium in the bladder for the number of hours desired. This is preferable to the plan of leaving a cystoscope or rigid applicator

FIG. 376.—AUTHOR'S EQUIPMENT FOR RETAINING AND APPLYING RADIUM ELEMENT IN THE BLADDER.

in the bladder for any considerable length of time. The patient urinates alongside this applicator.

This cystoscope has proved definitely practical for the above-mentioned objects. Once the sheath has been introduced into the bladder

the several interchanges from one to the other of the above-mentioned instruments are easily made and without disturbing or incommoding the patient. The caliber of the sheath is 24, French. The beak is short, providing easy manipulation in the bladder.

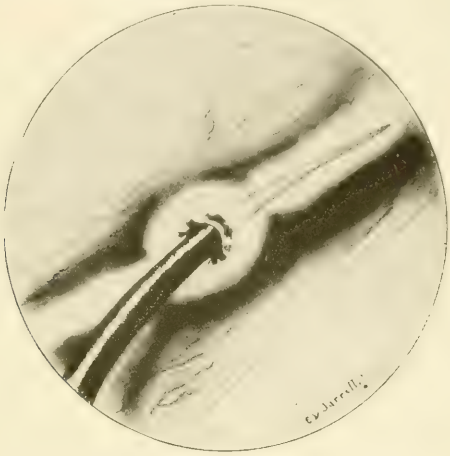

FIG. 377.—GARCEAU URETERAL BOUGIE ENTERING AND DILATING STRICTURED URETERAL ORIFICE. FIRST STEP OF OPERATIVE ATTACK.

Another prior model of the author's universal cystoscope is slightly different from the above model B, in that its lenses are slightly larger, affording a little more light and field of vision, but in this instrument certain telescopes are provided for ureteral catheterization and certain others for operating.

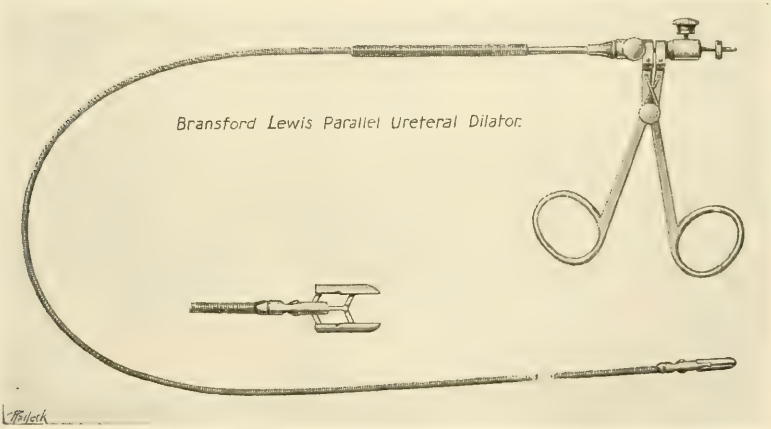

FIG. 378.—AUTHOR'S PARALLEL MODEL OF URETERAL DILATOR, OPEN AND CLOSED.

The simpler model (B) provides for the passage of the ureteral operating instruments and is probably more acceptable for general use.

In his endeavors at developing instruments that would prove more positively efficient for attacking ureteral stricture and stone the author

has found much difficulty in finding a solution of the mechanical problems involved—the combining of sufficient power with slenderness and delicacy so necessary for such instruments. With his graduated ureteral bougie (Fig. 377) Garceau fulfilled a most exacting demand for dilating

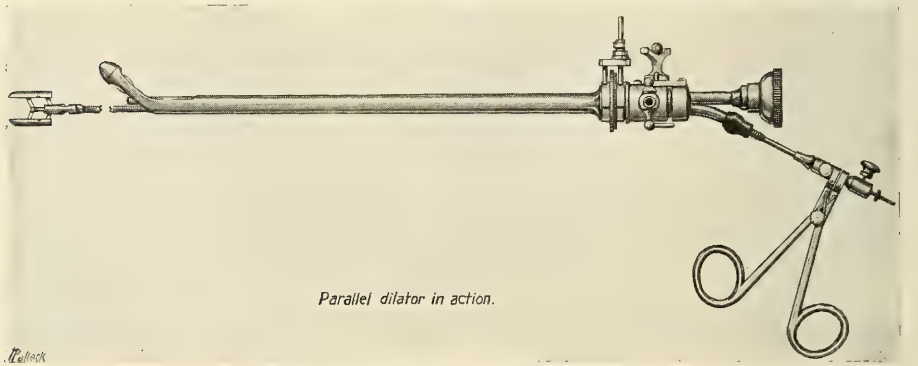

Fig. 379.—Application of Parallel Dilator.

ureters in one way, provided the bougies could be passed up the ureter far enough to bring the thicker part of the shaft in contact with the strictured area, dilating it at the same time.

But where a stone or a kink stands in the way one of the metal dilators (Fig. 378) of the author may be used to better advantage by applying

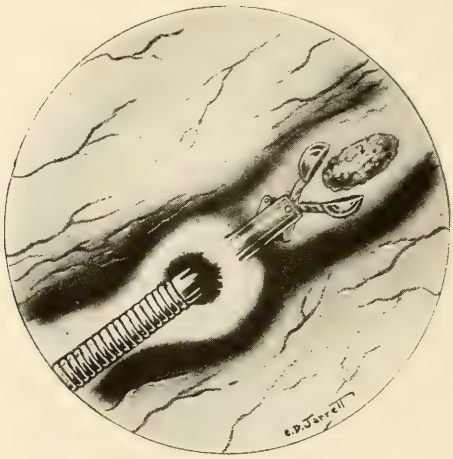

Fig. 380.—Ureteral Forceps Ready to Grasp Stone in Ureter.

its divulsing force *at the point of constriction,* whether at the orifice or higher up (Fig. 379).

Moreover, by means of metal dilators certain effects may be brought to bear on a ureteral stone unattained by the ureteral bougie. They may be used for dislodging a stone from its habitual location or attachments, possibly facilitating its descent in the ureter in this way; or, in case ample dilatation has been accomplished to make it a safe procedure,

the stone may possibly be grasped directly by the forceps and extracted. This, however, is not the usual procedure, the more gradual and safer method of successive dilatings, first providing a larger channel for the passage of the stone down the ureter to its lower end, whence it is either expelled into the bladder by the *vis a tergo* of the urine and peristaltic action of the ureteral muscles, or is removed by the direct action of a forceps or dilator (Fig. 380).

The author has removed stones by the more direct instrumental method (grasping and withdrawing) in 3 instances, typical of which is the following:

Miss E. B., age twenty-five. Pain in left lumbo-ureteral region for past ten years; at times so severe as to require hypodermics of morphin and prolonged general anesthesia.

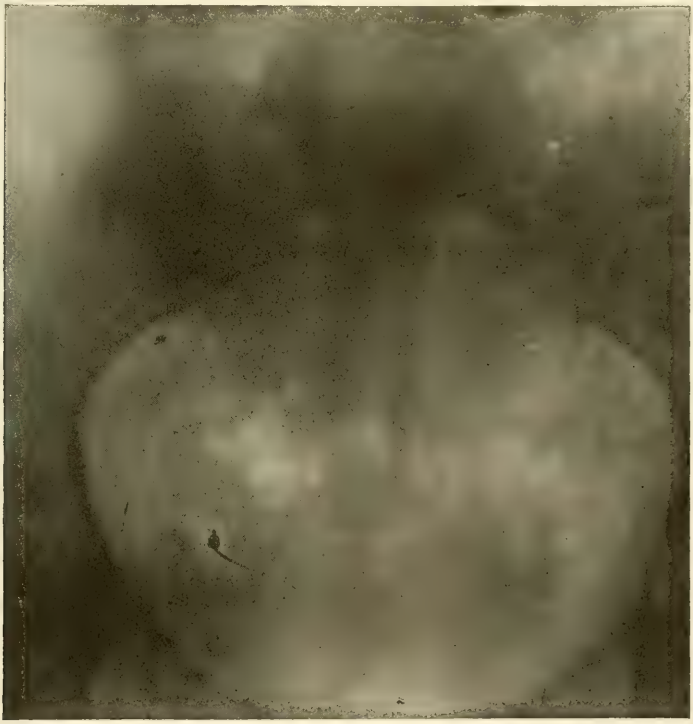

Fig. 381.—Ureteral Catheter in Contact with a Triangular Stone which was Removed by Direct Grasp of the Forceps, Case of Miss E. B.

Increased frequency of urination, until latterly it has been about every half-hour in daytime and twice nightly.

Examination: Marked tenderness of the left kidney and ureter. A small triangular-shaped stone was shown in the left ureter, both by catheter and catheter-obstruction and catheter radiogram, located about 4 cm. above the ureteral orifice (Fig. 381).

November 8, 1918, dilating of the rather contracted ureteral orifice and channel below the stone, gaining a definite enlargement of the caliber. No endeavor to grasp the stone.

November 15th repetition of the above, using satisfactorily the ureteral dilator, parallel model, until it passed in and out readily. Directly afterward the ureteral

forceps was inserted, its jaws held widely open as they approached the stone. The grasping of the stone was evidenced in two ways: By lack of closure of the forceps handle and by the lessening of easy passage through the ureter in efforts at withdrawal. Indeed, had not the precaution of wide dilatation of the ureter been observed, much difficulty would probably have been met with in the withdrawal. The triangular shape of the stone, added to the space occupied by both stone and forceps combined, produced this effect. But inasmuch as a good ureteral caliber had been secured beforehand, the extraction was made without much difficulty; and the stone still held in the jaws of the forceps was plainly visible through the cystoscope.

The patient has had no further symptoms of stone or colic, and is re-established in her regular vocation.

Direct Removal of Stone by Ureteral Dilator.—Dr. M. H. T., age forty-four, had had symptoms of ureteral colic for nine months prior to his first visit on July 29, 1918.

Fig. 382.—*x*-Ray Shadows Apparently in Line of Ureter.

At the first cystoscopy, July 31, 1918, no obstruction was felt to the catheter, although a radiogram previously taken seemed to show a stone in the right ureter. The parallel ureteral dilator was used along the lower 2 inches of the ureter; and on withdrawing it we were much surprised to note a small oblong stone retained in the bars of the instrument.

In certain other instances it seemed impossible to grasp the stone, even though an *x*-ray showed it apparently in contact with the end of the forceps. In such cases it is necessary to resort to open incision for removal.

Differentiation Between Stone and Phlebolith.—It is not considered necessary again to dilate on the liability of radiography alone to

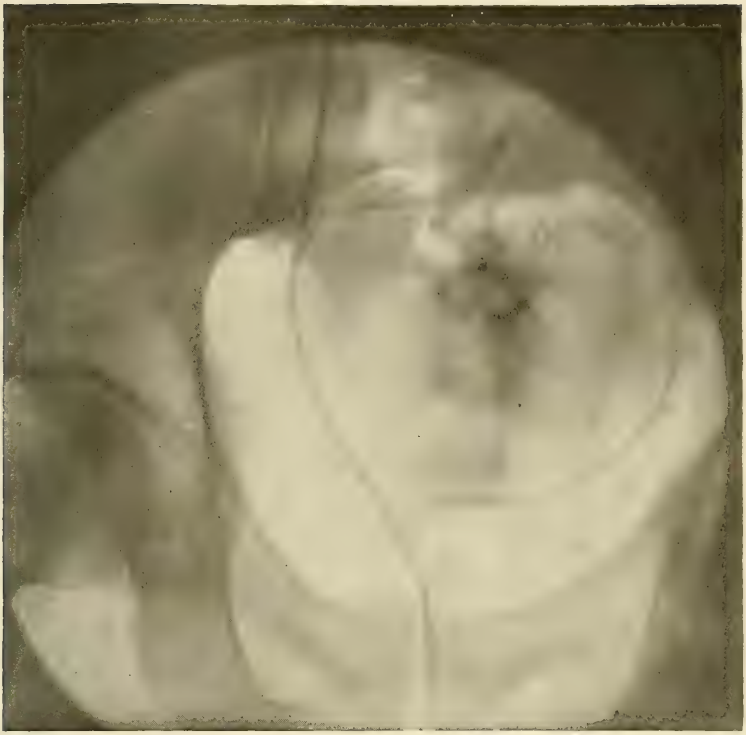

FIG. 383.—URETERAL CATHETERS DIFFERENTIATING THE LOWER TWO SHADOWS, BUT APPARENTLY IN CONTACT WITH THE THIRD (UPPER SHADOW).
Same case as Fig. 382.

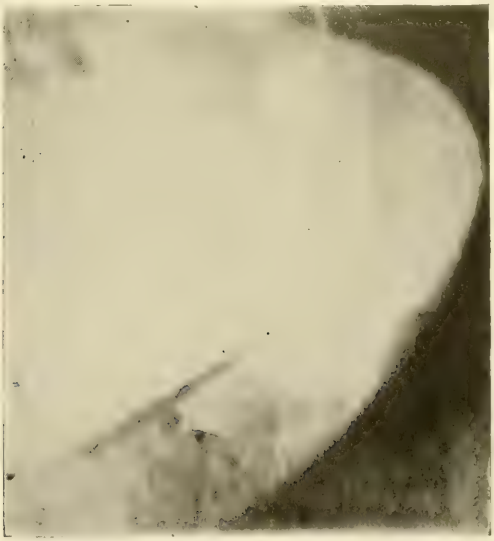

FIG. 384.—*x*-RAY OF UPPER SHADOW, APPARENTLY IN CONTACT WITH CATHETER: POSSIBLY A STONE.
Same as Figs. 382 and 383.

mislead the unwary in regard to shadows apparently in the line of the ureter in urinary cases. This has been discussed sufficiently often of

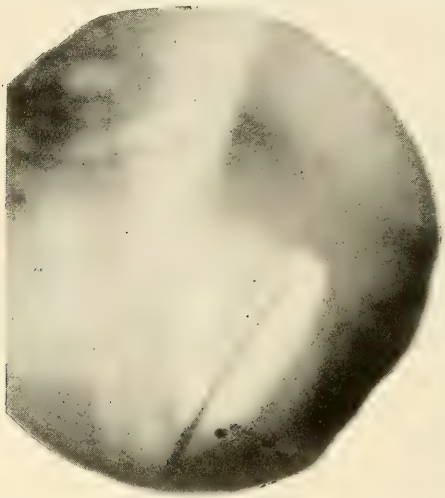

Fig. 385.—Ureteral Forceps in the Same Ureter, but Displacing it from Contact with the Suspected Shadow and Identifying the Latter as a Phlebolith.

recent years to make it a familiar subject to all students, reinforced as it has been by the numerous instances in which surgeons, relying on

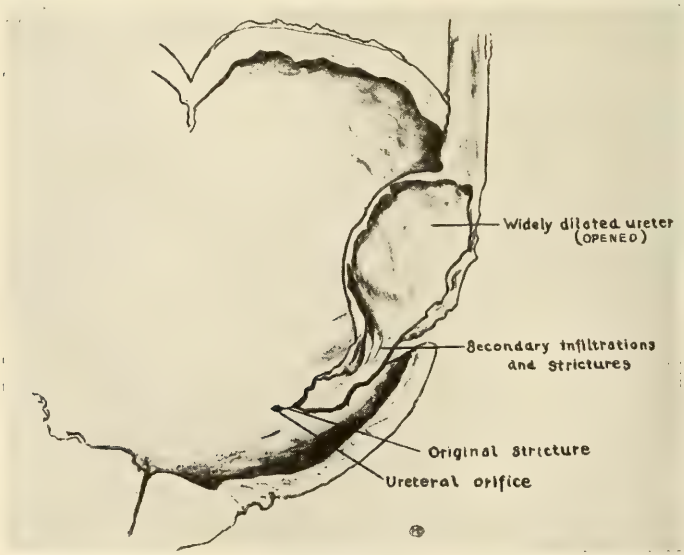

Fig. 386.—Postmortem Specimen of Ureter Strictured at the Lower Orifice and Dilated Above.

x-ray shadows alone, have cut in only to meet with the embarrassing situation of finding *no stone present*, the shadow proving to be only that of a phlebolith or some such innocuous material.

Such experiences have dictated the use, in suspected cases, of radiography in connection with the cystoscope and radiograph catheter, to determine whether the shadow is in the line of the ureter or at a distance from it (Fig. 382). If at a distance, there is no stone.

If the shadow lies in the line of the ureter (Fig. 383) there may yet be some doubt as to the presence of a stone. It might be a phlebolith and just happen to be in the line of the ureter, as indicated by the catheter shadow.

Fig. 387.—*x*-Ray of Strictured, Kinked, and Tortuous Ureter (of the Sole Remaining Kidney). Narrow Stricture May Be Observed at the Lower End of Ureter.

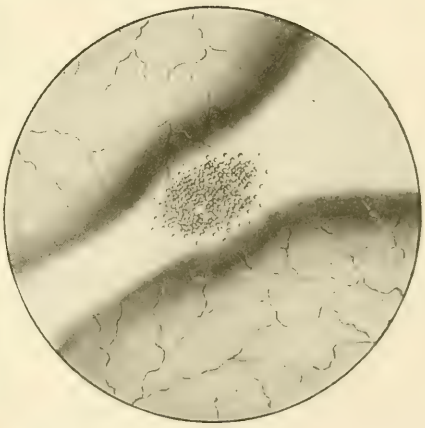

Fig. 388.—Cystoscopic Appearance of a Strictured Ureteral Orifice Through which a Minute Droplet of Pus is Oozing.

In order to complete this differentiation, in which there was much doubt, the author first took a radiogram (Fig. 384) which showed a shadow apparently in contact with the ureteral catheter (Fig. 385). Not satisfied with this result, he replaced the soft catheter with a metal forceps in the same ureter and had another radiogram taken. The shaft of the forceps being more rigid, straightened the ureteral channel, giving it a different course and bringing it out of line with the suspected shadow, stamping it at once as a phlebolith and not a stone (Fig. 385);

this differential sign is suggested as promising good service in certain instances.

Radiograms taken stereoscopically or taken at two different angles with reference to the radiograph catheter may serve the same purpose.

Ureteral Stricture.—In some quarters there has been a tendency to doubt the reality of ureteral stricture or, at least, its frequency. The

Fig. 389.—A Large Pyonephrotic Kidney Resulting from the Strictured Orifice Shown in Fig. 388.

accompanying illustrations of actual conditions can leave no doubt on the subject, furnishing as they do the reproduction of postmortem and living specimens of the condition (Figs. 386–389).

They also furnish the suggestion that an earlier recognition, with appropriate treatment of the cases, would have had a different and happier result.

INCISION OF THE URETERAL ORIFICE

This is frequently necessary for the release of a ureteral stone or for the enlargement of a constricted orifice (Fig. 390). Ureteral stricture located either at the orifice or further up is sometimes so dense and

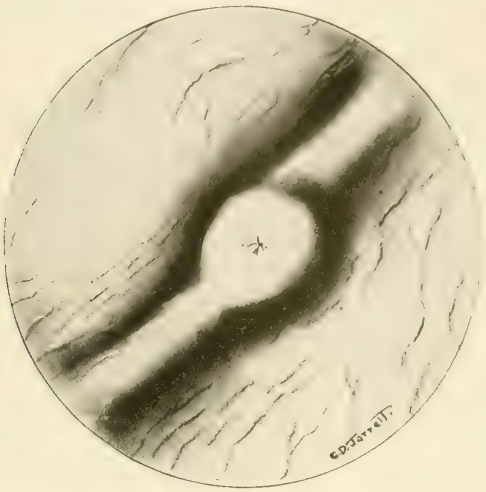

Fig. 390.—Cystoscopic View of Strictured Ureteral Orifice.

resistent, from chronic indurative inflammation, that the use of any dilator is at first impracticable and the necessity of incision is apparent. The ureteral scissors (Fig. 391) mentioned in Vol. III was found ser-

Fig. 391.—Author's Scissors Cutting a Ureteral Orifice.

viceable in such conditions except that sometimes the orifice tended to slip out of the scissor blades and render the cutting ineffective. The ureteral knife (Fig. 393) has recently been developed and meets this objection satisfactorily. It is introduced while closed, is then opened

slightly, and cuts from within outward. It is obvious that the *incision must be directed toward the cavity of the bladder* to be innocuous.

Fig. 392.—Result of Incising the Ureteral Orifice.

Fig. 393.—Author's Ureteral Knife.

No detrimental effect has thus far been reported from incision of the ureteral meatus. Braasch[1] has attested the innocuousness of the resulting patency of the ureteral orifice.

DIAGNOSIS OF URETERAL STRICTURE

The manifestations of ureteral stricture are various and often elusive; which no doubt partially accounts for their failure of recognition in many cases until the final destruction of the kidney above has taken place.

The symptomatology often closely simulates that of ureteral stone. There are sudden attacks of colic, moderate or extreme in severity, with pain running down the course of the ureter, perhaps into the testis or labium of the corresponding side.

These attacks often arise from the hanging of a plug of mucopus behind the stricture, blocking the ureter and causing the various reactions of pain, fever, tenesmus, etc., that incarcerated stones do; hence the analogy of their symptoms. Indeed, stone and stricture often develop coincidently and give further reason for duplication of symptoms. In other cases the pains are more continuous and less severe, consisting of an ache along the ureter or being reflected into the kidney of that side.

There may or may not be blood-cells, pus, or bacteria in the urine in the earlier period of development; but in the later periods these are likely to be present.

Strictures occur as a result of the presence of stone, tuberculosis, focal infections, adhesions, external pressure from trusses, etc., and their symptoms are necessarily modified by these.

But the diagnosis seldom rests on the symtomatology, which, however, serves to direct attention to the use of methods of reaching a diagnosis, namely, physical examination, including the required phases of cystoscopy.

A strictured orifice may sometimes be recognized by observation through the cystoscope. It may be minute in caliber and fail to open in discharging urine in the natural manner. Or it may be rigid from infiltration, and though appearing of good caliber, on attempting to introduce a catheter it is found to be contracted, resistent, and immobile.

Strictures higher in the ureter are best demonstrated by pyelography. When the lower ureteral orifice is dilated or sufficiently patent for regurgitation of fluid from the bladder, the pyelogram may be made by filling the bladder with the appropriate fluid, elevating the patient's pelvis, and then taking the picture (see Fig. 387 made in this way). If the conditions are not appropriate for this method, a catheter must be inserted and the injection made through it. Collargol solution (10 to 15 per cent.) has been much used; but because of severe reactions

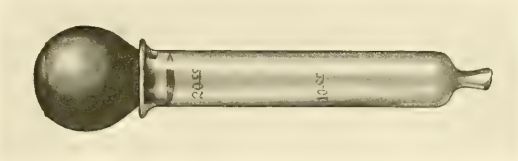

Fig. 394.—Ureteral Syringe.

or even deaths ascribed to its use, it has largely been replaced by thorium solution, sodium iodid, or sodium bromid solution, 15 to 25 per cent. These may be injected with a ureteral syringe (Fig. 394) until the patient complains of distention pain.

The radiogram should show any narrowings, kinks, or variations in caliber of marked degree, together with similar evidence of a dilated renal pelvis. Fowler[2] has shown kinks in the ureter by radiographing the injected ureter with the patient first in the reclining posture and then while erect. The descent of the kidney demonstrates the kinking of the ureter in the second pyelogram.

A large-sized ureteral catheter is best used in this work; in the first place, for blocking off, as much as possible, a return flow of the fluid into the bladder before the picture is taken; and in the second, to permit prompt emptying and irrigation of the pelvis at the finish. If the ureter should be so dilated that the fluid is not well retained, an elevated pelvic posture is of service.

While the gravity apparatus of Thomas was safer than a syringe in connection with the use of collargol, it is hardly necessary with the other solutions named; and the ureteral syringe shown in Fig. 394 is safe and more convenient.

For the final determination of ureteral stricture Hunner[3] places greatest reliance on the use of the wax-tipped catheter, to which is added a wax bulb an inch or so above the tip. He claims that the bulb demonstrates the narrowings of strictures by hanging in them or jumping from them in being withdrawn. Scratch marks on the tip would indicate the presence of stone (Kelly).

One must not conclude too readily that just because a catheter is blocked in its passage up the ureter a stricture is thereby indicated. The catheter is often obstructed in normal ureters by the tortuous course of the tube, or by spasmodic contraction of its muscles, or by the angle at which the catheter enters the ureter. A change in the angle or curve of the catheter or a pause for a few moments may surmount the difficulty and permit the free passage of the catheter, removing the suspicion of stricture.

STEPS OF CYSTOSCOPIC PROCEDURE FOR THE RELIEF OF URETERAL STRICTURE

Stricture at the Ureteral Meatus.—If dense and rigid, endeavor to insert a dilating filiform bougie or a Garceau dilating catheter the shaft of which is much larger than the tip. Either of these incidentally divulses and dilates the narrowed orifice as it passes up the ureter. This amount of enlargement facilitates the introduction of a blade of the scissors (Fig. 391) or the ureteral knife (Fig. 393), or even of one of the ureteral dilators, all of which may assist in overcoming the pathologic narrowing. As with urethral narrowings at the meatus, incision is more enduring and effective than dilating, the latter having to be repeated a number of times for permanent effect.

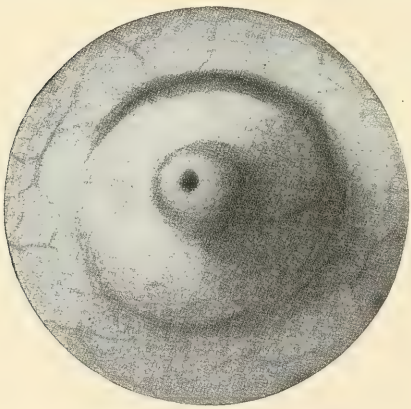

Fig. 395.—Ureterovesical Cyst; Case of Dr. Clarence Martin.

Ureterovesical cyst with ballooning of the mucosa into the bladder (Fig. 395) is best treated by free incision after sufficient enlargement of the orifice has been obtained to permit the introduction of the cutting instrument (preferably the ureteral knife).

Treatment of Ureteral Stricture Above the Lower Orifice.—Obviously, it is not judicious to attempt incision of a ureteral stricture located higher than the outlet itself. Penetration of the wall, with extravasation of urine, abscess, etc., might readily result. But other measures, effective and harmless, are still available. The Garceau graduated bougie may be used, as shown in Fig. 377; after which, if the stricture be located not higher than 3 or 4 inches up, the parallel dilator may be employed. The suggestion of Buerger to use high-

frequency electricity with insulated bougies is of questionable propriety because of the possibility of penetrating the ureteral wall. The use of flexible or metal dilators is attended by no such danger.

STONE IN THE URETER

The successive individual steps of cystoscopic manipulation for the removal of ureteral stone depend mainly on the size and location of the stone. If located at or within the lower orifice it is practically a certainty that a stone can be removed by means of the cystoscope and without the necessity of suprapubic cystotomy.

The spreading within the ureteral orifice of a dilator or forceps may at once secure the added space desired and may be followed by the popping out into the bladder of the stone that has lain there for months or years; or if the rim of the orifice be too indurated for dilation, it may be incised superiorly with the scissors or ureteral knife, as previously described. In many instances the stone may be removed without either

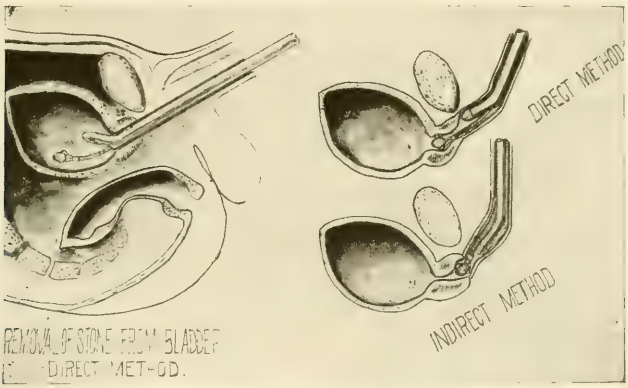

FIG. 396.—METHOD OF REMOVING SMALL STONES FROM THE BLADDER TOO LARGE TO PASS THROUGH THE CYSTOSCOPE SHEATH.

of these measures by simply grasping it directly with the bullet forceps (Fig. 380), the chief obstacle to this being the possible slipping of the stone backward into the ureter. If this occurs, the course most advisable is that of dilating or incising the orifice, as the stone will be sure to come down again, and will in all probability then pass through the enlarged orifice.

Once in the grasp of the forceps or within the bladder, the further removal is easy. It is either drawn out through the sheath or, if too large to pass through the sheath, is drawn out "in parade," sheath, forceps, and stone being brought out together, as illustrated in Fig. 396.

Stone Higher Up in the Ureter.—By far the greater proportion of stones that are arrested in transit through the ureter are arrested at or near the lower end, just the location that is most difficult of access for open operation, but most favorable for cystoscopic removal.

On the other hand, the incarceration of a stone higher up in the ureter, even though held there by a ureteral narrowing or stricture, does not preclude its being removed by cystoscopic measures. The plans

indicated under such circumstances are well defined and practicable. They consist in first dilating the ureteral channel below the stone with a graduated dilating bougie, as shown in Fig. 377, and later by means of the metal dilator, unless it is higher than 3 or 4 inches (Fig. 397). When sufficient dilatation has been attained the way has been paved for the descent of the stone to the lower part of the ureter, whence it may be removed as previously described.

As before remarked, it is decidedly inadvisable to try to grasp a stone within the ureter for direct removal unless wide dilatation of the channel has first been attained, permitting the passage outward of both stone and forceps together (Fig. 397).

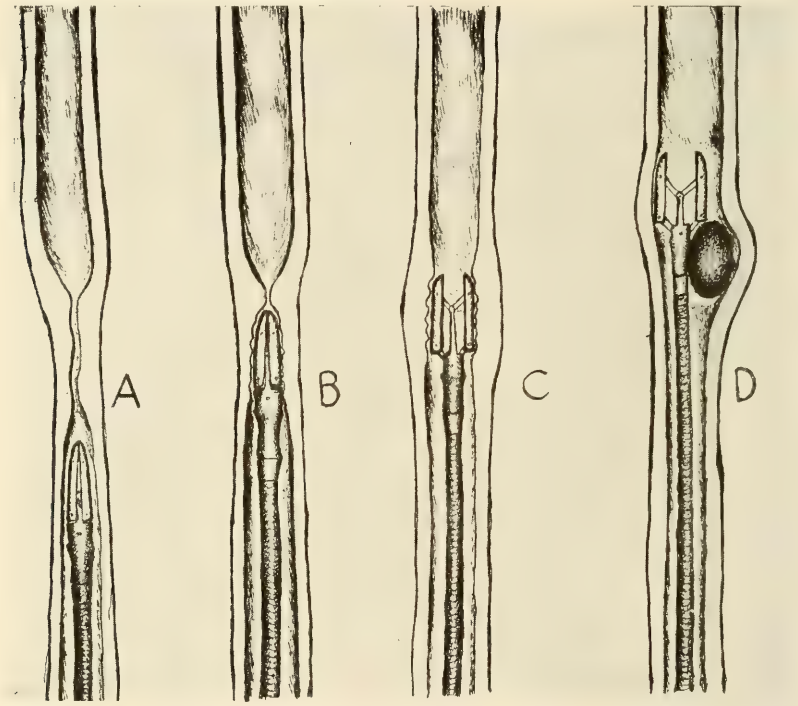

FIG. 397.—*A*, *B*, *C*, DILATOR IN STRICTURED URETER. *D*, TRACTION ON STONE IN URETER.

Injection of Oil, Glycerin, or Medicated Solutions for the Release of Ureteral Stone.—While there is no objection to the use of these agents for the purpose of facilitating the descent or escape of ureteral stone, they have proved of very little efficacy in the author's hands, and he is convinced that more definite and active measures are required to overcome the physical obstacles present. Such agencies often used are: Liquid albolene or liquid vaselin; glycerin; 2 per cent. solution of papaverin injected through the ureteral catheter. They are supposed to lubricate the ureteral walls or relax their natural contractility. Where there is pronounced spasmodic contraction of the ureter they may do good in relieving this.

TRIGONITIS AND URETHROTRIGONITIS IN WOMEN

A condition has been observed in women that, while causing much and prolonged annoyance or even misery, has apparently not received the attention it deserves. These inveterate sufferers complain from year to year—often fifteen to twenty-five years—of undue frequency and urgency, especially in connection with physical activity of any kind, doing household duties, automobile riding, walking, etc. Desire to urinate seems to initiate every move, and the question that outweighs all others is that of an opportunity for the next urination.

There is no question about the reality of the suffering nor the frequency of this condition among women. What contributes largely to the lack of recognition of the condition is its failure to present pronounced local evidences. The urine is often clear as crystal and abundant in quantity—indeed, beyond criticism from every standpoint. The local examination fails to show outspoken inflammation, infection, or other pathologic process; so that the natural inclination is to prescribe a placebo and let it go at that.

An experienced observer, however, will readily detect with the cystoscope or endoscope a hypersensitiveness of the mucous membrane of both the urethra and the vesical neck, together with an undue tightness or actual contraction, in many instances, of the urethra itself. This latter may be attested by the use of a Kollman dilator, which at the first sitting may be capable of being dilated to only 27 or 28, instead of 35, French, the normal.

The undue tightness of the urethra, either spasmodic or organic, is often further demonstrated by the presence of residual urine. In women who consider themselves unable to hold urine well from 8 to 12 ounces of urine have been disclosed by catheterization after voluntary urination. Such urine may be either clear or infected.

The cystoscope and endoscope show in the first place a clear and healthy mucous membrane in the bladder excepting the trigone and the urethra. The general vesical mucosa presents the normal pinkish-salmon color, with individual arborescent vessels. But when the instrument brings the trigone into view, a velvety reddish area is seen, deeply conjested, the injection being continued into the urethra. On contact with these areas the patient complains of pain.

Instead of being a "cystitis," as it is usually termed, it is really a urethrotrigonitis. Rather a urethral than a vesical affection.

The treatment that secures relief must be directed to the urethra rather than to the bladder. Many such cases have had their bladders washed innumerable times without any lasting benefit. Such washings would be serviceable enough if following the more essential urethral treatments, such as urethral dilatings, urethral instillations, and endoscopic applications. The promptitude with which improvement follows such treatments is as surprising as it is gratifying to the doubting patient, who may have long since lost hope of relief from any source.

Complete and permanent relief has been secured in many women who have suffered for as long as thirty-five years. Some have com-

plained since girlhood. Indeed, the same condition is often seen in girlhood, with the same symptomatology and pathology. Occasionally

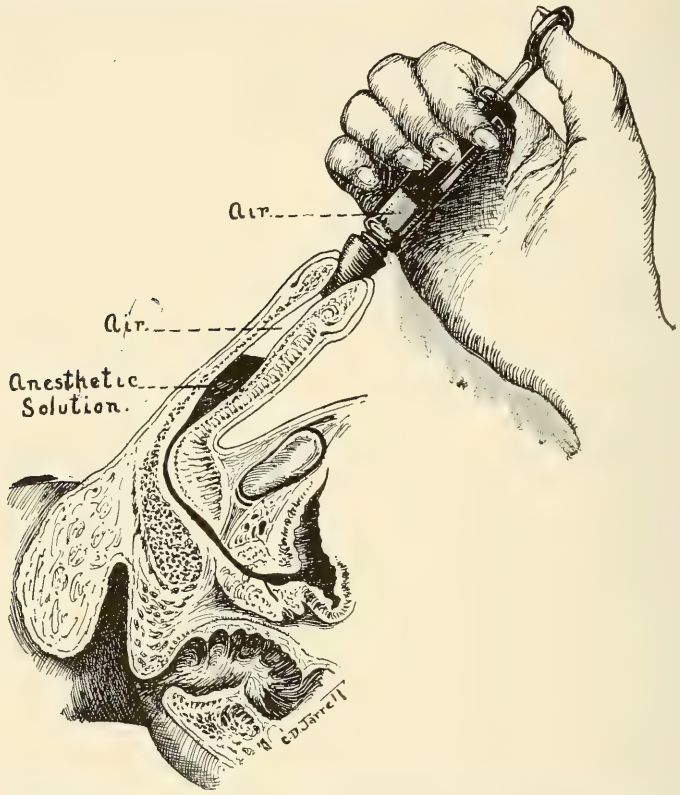

Fig. 398.—Method of Applying Anesthetic Solution by Means of Anterior Urethral Syringe (Air-cushion Being Used to Advance the Solution).

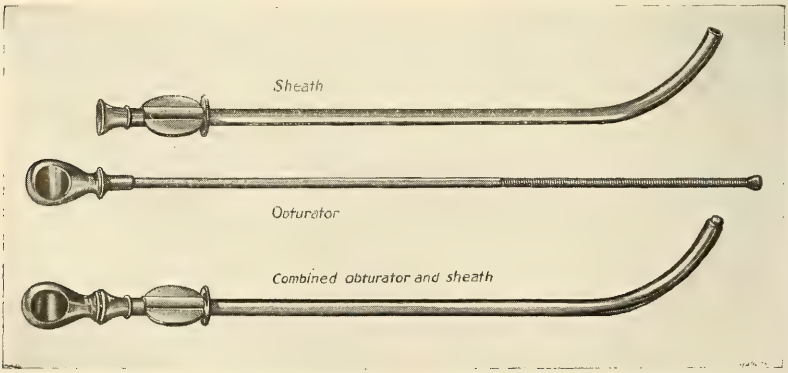

Fig. 399.—Author's Latest Model of Urethral Tablet Depositor.

a chronic bacteriuria (colon bacillus) is superadded, but it seems secondary rather than primary.

A positive diagnosis having been made, the treatment found most serviceable has been the following: In all hyperesthetic or sensitive cases effective local anesthesia must precede all local measures. With the bladder empty an anterior urethral piston-syringe is used to inject 20 or 30 minims of 5 per cent. procain or cocain solution slowly, which deadens the sensitiveness of the urethra; it is immediately followed by the use of a tablet depositor (Figs. 398–400), with which one or two tablets (cocain or procain) are dropped into the urethra (not the bladder), and when liquefied, smeared over the membrane of the urethra and trigone. Patients who have received local treatments without local anesthesia are not backward in expressing their gratification at the difference between the two. In addition to this the treatments can be carried out more completely and efficiently with the patient quiet and unresisting. Most of such patients are overwrought and unnerved, but a painless first treatment works wonders in securing their confidence and support.

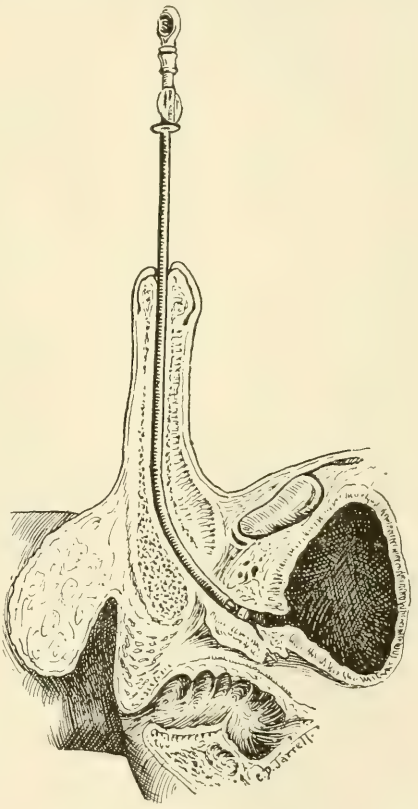

Fig. 400.—Depositing a Cocain Tablet in the Prostatic Urethra by Means of Author's Urethral Tablet Depositor.

The Kollman dilator having been inserted just within the bladder, is enlarged until some resistance is felt or the patient begins to complain of the stretching. The dilator is held at this point a minute or so to permit the urethra to relax and accommodate itself to the caliber thus far attained. This is soon shown by the patient's prompt acknowledgment that the pain is disappearing; whereupon further dilatation, a degree or more, may be made. At the first séance 28 to 32, French, may be registered. At the second, one may perhaps go to 33 or 34. After that one degree may be added at each sitting. The benefit being rapidly attained is most gratifying to the patient.

In long-standing cases the dilatings may have to be taken up to and continued for a long time at 45, French, the limits of the instrument. If the urethra still shows that the stretching has not yet overcome the tendency to spasmodic recontraction, it is often found serviceable to use a uterine dilator with moderation to secure the additional effect.

The dilatings are made at intervals of three to five days, according to the individual cases; and are invariably followed by the introduction of a soft-rubber catheter, emptying of the bladder, injection through it of 5 or 6 ounces of a mild antiseptic solution (3 per cent. boric acid or 1 per cent. silvol or argyrol solution), withdrawal of the catheter, and the urination of the fluid by the patient. The urethra thereby receives a soothing as well as an antiseptic lavage.

In chronic and rebellious cases the dilatings are alternated with endoscopic applications to the urethra and vesical neck of graduated strengths of silver nitrate solution—5, 8, 10 per cent. The main difficulty in making these applications is that of clearing the field of the urine just at the urethrovesical junction, where a strong application should be made. For this purpose it is well to have the patient's pelvis well elevated (lithotomy position), and to make use of a bulb aspirator to which is attached a long straight metal tube. This dries the field and prepares it to receive the application on a cotton swab. Successive applications are made all along the urethra as the endoscope is withdrawn. While the immediate effect may be somewhat disagreeable, the later effect is surprisingly beneficial. Another variant is the instillation of 5 or 10 drops of nitrate solution $\frac{1}{2}$ to 3 per cent. in strength; but the endoscopic is likely to prove the more effective method.

If the condition of irritablity is accompanied by marked infection a solution of potassium permanganate may prove more efficient than any other, but it must be used only in gradually increasing strengths, from 1 : 5000 to 1 : 2000.

By many the female urethra has been considered exempt from contracture or stricture. Nothing could be farther from the truth. Urethras of the female are strictured as definitely, although not as frequently, as those of the male; and their recognition and appropriate treatment are demanded as urgently as in the case of men.

ALKALINE CYSTITIS WITH INCRUSTATIONS

A form of cystitis occasionally noted is that in which an inveterate tendency to the production of calcareous plaques and deposits at various points in the bladder is evident. Such deposits sometimes closely resemble individual calculi to the cystoscopic view, but are found to be closely adherent to the vesical mucosa, which bleeds when they are scraped off. The deposits occur in connection with malignant growths of the bladder, obstructive processes in the urethra or prostate, renal tumor or chronic infection, or may be independent of all of these and may simply accompany chronic cystitis. Ordinary urinary antiseptics may provoke little if any response. The two most effectual measures are periodic urethral dilatings, and the injection into the emptied bladder of an emulsion of Bulgarian bacilli, as suggested by Caulk.[4] The proliferation of the Bulgarian bacilli in the bladder seems harmless and is easily cut short, if need be, by the injection of any mild antiseptic solution. The progressive diminution in the area covered by the calcareous material is plainly evident in successive cystoscopies.

The emulsion is prepared as follows: In 1 ounce of sterile warm water place 3 or 4 of the Bulgarian tablets and dissolve by stirring. Empty the bladder by a rubber catheter and immediately inject the emulsion, directing that it be retained as long as possible. Do not use any antiseptic that would tend to defeat the purpose by sterilizing the emulsion. The injection may be made daily until the inoculation "takes" and proliferation begins, as shown by neutralizing, then acidifying the alkaline urine. Incidentally it may be mentioned that the application of the Bulgarian bacilli emulsion often favorably influences an infected suprapubic wound that is overrun with alkaline urine.

ATONY AND VESICAL RETENTION OF OBSCURE ORIGIN

Of late years a number of discussions of this subject have appeared in the journals.[5] One school has expressed the belief that such atony represented the result of senile degenerative changes in the walls of the bladder analogous to arteriosclerosis, and was therefore apt to be permanent; while others, less pessimistic, believe that the effectual removal of the obstructive factor, whatever it is, may effect a cure.

The practical importance of this topic, in its clinical and therapeutic relations, is obvious. One view means inveterate invalidism; the other, restoration on recognition and the removal of the cause. The author is a firm partisan of the latter view.

A normal "balance of power" exists in the processes of filling and emptying of the bladder, by which the sphincters contract and retain the urine until, under a proper nervous impulse, they relax, and make way for the passage of urine. At the same time the urine is impelled through the passage by direct contraction of the detrusors of the bladder wall, also acting under nervous impulse. Derangement of this balance arises from two sources only: (*a*) physical obstruction of some kind, or (*b*) disturbance of the nervous mechanism controlling urination.

Derangement of this balance from either of these sources may result in obstruction or urinary retention. Typical of derangement from mechanical obstruction is that presented by prostatic hypertrophy or contracture without hypertrophy. Typical of derangement from nervous influence is that resulting from spinal syphilis (tabes) inhibiting control over the sphincters or the detrusors—by which the patient is unable to relax his voluntary sphincter, or the sympathetic nervous system is unable to provoke efficient action on the part of the detrusors. Spinal syphilis is a most fertile source of such interference. This fact, if appreciated, would account for a very large portion of the so-called "unaccountable cases of obstruction," as is daily being proved by the Wassermann blood test.

The major portion of the remainder of the so-called "unaccountable" cases of obstruction, it is believed, on searching investigation, would be disclosed as originating in one of these obscurer forms of mechanical obstruction at the neck, viz., contracture, not demonstrable by ordinary modes of investigation, but clearly proved by suprapubic cystotomy and direct palpation with the finger; or proved by a therapeutic test—

the regular use of deep urethral stretchings with the Kollman dilator, by which the narrowed outlet is enlarged, urination is improved, and residual urine is eliminated.

The practical value of these views, if they are correct, appears in the happy results to the patients—restoring them from apparently permanent disability to functional activity and health.

The author has seen many of both classes of cases thus restored after periods of disability varying from five to forty years in duration.[6]

Contracture at the neck affects the male at any period of life. It was so severe in a recent case, a boy of two years and eight months, that all efforts at urination were accompanied by straining, severe pain, and various maneuvers by the patient and his parents to facilitate urination. Later urine could be passed only by the catheter, the introduction of which became more objectionable and difficult the oftener it was used. The patient finally had to be etherized each time for this purpose. Perineal incision demonstrated marked contracture at the neck. This with the free incisions secured striking and complete relief from the painful urination that had previously prevailed. In other cases difficult urination from the same source has been traced all the way from infancy through adolescence and into middle life—always designated as "unaccountable" or unrelievable, in harmony with the inadequacy of diagnosis and treatment. In one such instance a man twenty-nine years of age stated that he could not remember when he had not labored at urination, even in earliest infancy. His bladder and the pelves of the kidneys were widely dilated from backward pressure —one kidney had to be surgically drained for relief of marked pyonephrosis.

Following the discovery and relief by incisions of the contracted vesical neck there was restoration of health and functional capacity far in excess of any previous period in his life. This result has been confirmed by later reports twelve years after the operation.

Restorations of a similar kind and almost as striking have been made in patients who habitually carried 20 to 26 ounces of residual urine, the result of early spinal syphilis, totally unsuspected, as other indications of the disease had not been observed up to that time. Local and systemic treatment by dilating the neck, salvarsan, and mercury was followed by a satisfactory result.

The requirements demanded of the profession are: Searching examination; accurate and comprehensive diagnosis; appropriate treatment. Surgical measures often inappropriately applied include prostatectomy, internal urethrotomy for supposed strictures, etc.

The author feels justified in presenting the following conclusions taken from the paper previously mentioned:

1. The exact causation of urinary retention should be sought for before adopting a plan of treatment.

2. It should always be found in one of two factors, viz.: (*a*) physical obstruction of some kind, or (*b*) disturbance of the nervous mechanism controlling urination.

3. There is no such thing as "unaccountable" atony of urinary retention; such a term represents an incomplete diagnosis.

4. There is no such thing as "incurable atony" except when it is caused by some nervous degenerative process (tabes, etc.) that precludes expulsive power.

5. Even when the retention and atony are caused by nervous degeneration much can be done by way of treatment, both locally and internally, to facilitate urination and improve the prevailing conditions.

6. Where the cause is physical obstruction its complete removal paves the way to restoration of the expulsive power.

7. The most frequent and important of the obscure, unrecognized causes of obstruction are: (*a*) Ill-defined contracture at the vesical neck (demonstrable sometimes only by palpation through the opened bladder or urethra); (*b*) unrecognized syphilis, acquired or hereditary, affecting the spinal centers.

8. Such conditions are by no means confined to adult life, and should be looked for and recognized at any age, from infancy up. They should be diagnosed and treated in accordance with the exact diagnosis always demanded by cases of urinary obstruction.

9. Syphilis is a surprisingly frequent cause of such conditions. Lack of syphilitic history or general nervous symptoms, in obscure cases, should not preclude investigation by means of a Wassermann blood test; and if this prove doubtful a Wassermann test of the spinal fluid should be made as well.

10. The supreme value of early recognition and differentiation of such cases appears in the opportunity it offers of affording appropriate treatment before the case has assumed the hopeless phases that preclude reclamation or benefit.

A final but too late recognition is a poor solace for a lifetime of suffering due to delinquencies in diagnosis.

INCONTINENCE OF URINE

Incontinence of urine in both sexes occurs from several causes and must be closely studied and correctly diagnosed in order to determine what measures are appropriate for its relief.

Many cases of supposed incontinence are only overflow incontinence, coming from retention and overflow of urine obstructed by prostatic adenoma, simple or maligant, low fevers, unconsciousness, paralysis of the bladder, etc.

Relief in cases of obstruction is to be obtained through removal of the cause, whatever it may be.

Incontinence from disease of the central nervous system, paralysis of the vesical sphincters (from paresis, tabes, etc.) is not amenable to operative surgery. That from mutilating surgical endeavors, overzealous "prostatectomies," etc., has been thought to be beyond surgical aid, and many such cases have been advised that their only recourse was the permanent wearing of a rubber urinal—a most unsavory and unsatisfactory makeshift. As a matter of fact, incontinence from inade-

quate sphincters, either in the male or the female, is amenable to surgery to a most gratifying degree.

FIG. 401.—YOUNG'S "BOOMERANG" NEEDLE HOLDER, USED IN OPERATION FOR CORRECTING INCONTINENCE IN THE MALE.

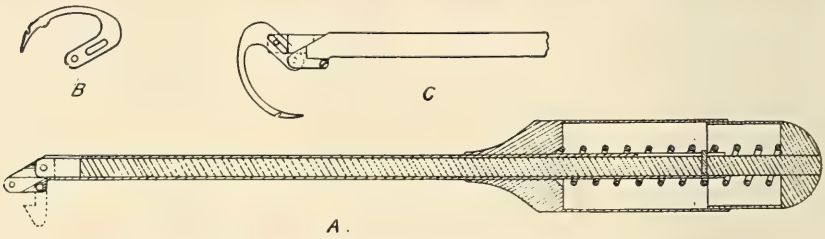

FIG. 402.—SAME AS FIG. 401 IN LONGITUDINAL SECTION.

A, Longitudinal section of "boomerang" needle holder (with needle detached) showing spring in handle which is compressed by the hand to cause the point of the needle to penetrate into the tissues and return toward the operator, and which when released draws the needle back through its tract. *B*, Free needle. *C*, Method of attachment of needle, which is held in place by means of a small clasp shown opened in *A*.

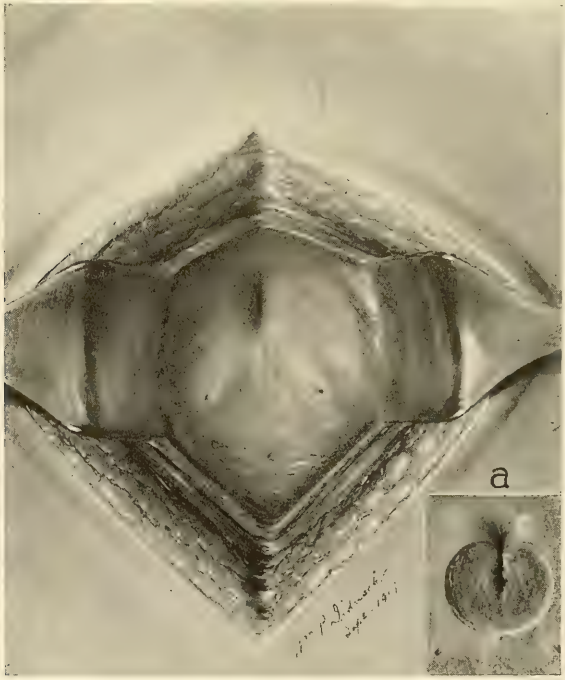

FIG. 403.—VIEW OF BASE OF BLADDER SHOWING DILATED INTERNAL VESICAL SPHINCTER. Insert (*a*) showing area denuded of mucous membrane preparatory to suturing. (Young.)

Incontinence in Women.—This often follows an injury to the sphincter incidental to childbirth; and failing sphincteric control shows

itself in a partial or total inability to retain the urine. It is not a question of frequent urination or irritation; the urine escapes involuntarily on any sudden movement, such as arising, or laughing, coughing, etc. The remedy lies in tightening the sphincter just at the vesical neck, after gaining access to it by incision through the vaginal mucosa. When

FIG. 404.—USE OF "BOOMERANG" NEEDLE HOLDER, SHOWING POINT OF NEEDLE ABOUT TO BE INSERTED INTO TISSUES. (Young.)

properly performed the operation is almost invariably successful. The operation as described by Kelly,[7] who has performed it many times, is as follows: "A Pezzer catheter is introduced into the urethra; the tube ought to be small, not over 5 mm. in diameter. With the patient in the lithotomy position, the posterior wall of the vagina is retracted and the

area at the neck of the bladder is brought down with either forceps or four guy sutures.

"The next step is to slit the vaginal wall down to the urethra and the bladder in the median line for about 1½ or 2 inches. The neck of the bladder should fall at about the center of the incision. The position of the neck is easily determined at all times by moving the catheter

FIG. 405.—THE NEEDLE HAVING BEEN PLACED, ITS POINT DIRECTED BACKWARD TOWARD THE OPERATOR, AN ASSISTANT LOOPS THE SUTURE IN THE EYE OF THE NEEDLE. (Young.)

to and fro and feeling its head, which presses close up against the urethra. The utmost care should be taken not to cut into the urethra or the bladder at any step of the operation. After making this median incision the vagina is further dissected off on both sides with tissue forceps and dissected away for a distance of 2 to 2.5 cm. around the neck of the bladder. This dissection may be made with blunt-

pointed scissors which push their way into the tissues, separate the bladder from the vaginal walls, and then cut the connecting fibrils. The dissection should be deepest at the neck of the bladder.

"When the detachment of the vagina from the bladder is completed the finger should be able to grasp one-half or two-thirds of the neck of the bladder, including the contiguous urethra. Sometimes the bladder wall is so thin that its mucosa shines through.

Fig. 406.—The Needle is Released and the Suture is Drawn Through the Tissues. (Young.)

"The next step is to suture together the torn or relaxed tissues at the neck of the bladder, using two or three mattress sutures of fine silk or linen passed from side to side. The first suture takes in about 1.5 cm. of tissue, is tied at once, when the succeeding suture may be passed outside this, further contracting and bringing together the tissues at the neck. This is the principal part of the operation, and when

done the mushroom catheter ought to be pulled out, the head of the catheter escaping with a little jump as it clears the tightened reconstructed sphincter at the neck of the bladder. The more or less redundant walls of the vagina, which have been detached in order to expose the sphincter area, are now resected so that the remaining tissues can be snugly brought together from side to side, so as to support the vesical area operated on and avoid any dead space. I prefer to do this suturing with a continuous fine catgut suture in one or two layers.

"The after-treatment is simple: No catheterization unless imperative, though sometimes it must be done for several days or even a week. A Gatch bed and a half-way-up posture from the very first, and then out of bed in a few days."

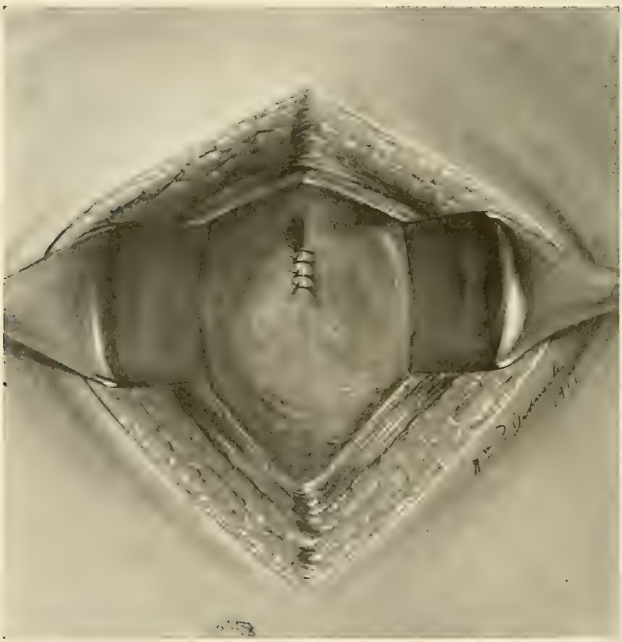

FIG. 407.—SUTURE LINE AFTER COMPLETION OF YOUNG'S PLASTIC OPERATION UPON INTERNAL STRICTURE. (Courtesy of Dr. Hugh H. Young.)

Incontinence in the Male.—The operation of Young[8] provides for sphincteric restoration by coincident attack on both the internal and external sphincter through suprapubic and perineal incisions.

"The trigone is fully exposed by suprapubic incision through the bladder, its mucosa is incised and removed, denuding the internal sphincter, which is brought tightly together from side to side by chromic catgut sutures. The bladder wound is closed, with a tube draining from its upper angle. Drainage is assisted by a vacuum apparatus. Through the perineum an oval incision is next made, including the scar tissue met with, down to the triangular ligament on each side, until the urethra is approached, the presence of a rubber catheter in the urethra rendering identification easy. If the posterior urethra is dilated, a

portion of its wall is excised and the two sides are brought together, narrowing it to the desired extent. The muscle tissue of the external sphincter is sought for on each side and approximated over the urethra, which also is closed by chromic catgut, a second or possibly a third line of sutures being required for that purpose. Even though muscular tissue cannot be identified, the structures substituting it are treated in the same manner and subsequently appear to take on the function of sphincter activity. A soft catheter is retained in the urethra for eight or ten days" (Figs. 401–407).

Results in two cases thus operated on by Young were all that could be desired, one having been relieved now for ten years, after having been completely incontinent for a year following a perineal prostatectomy.

VESICAL DIVERTICULUM

While prior to 1912 vesical diverticulum was looked on largely as a pathologic curiosity and inclined to be resistant to the various modes of treatment devised up to that time, this is no longer the case. Material advances have been made both in the recognition and operative relief of this most unfortunate and harassing malady, due, on the one hand, to the service afforded by cystoscopy and *x*-ray delineation for diagnosis; and, on the other, to the simplicity and efficacy of operative measures that have been popularized chiefly by Lower.[9]

The symptomatology of diverticulum possesses certain characteristics that lead one, if observant, to suspect its presence and to follow with the required physical examination that is practically sure of resulting in its recognition and plain demonstration.

There is a history, usually covering long periods of time, as the condition is insidious and well tolerated, of repeated efforts at urination rather than difficulty of effecting urination. The patient may be under the impression that he urinates easily but ineffectually, in that he passes only a part of the volume at a time and must repeat the act several times before he has finished; and even then he is conscious of a fulness or heaviness in connection with the bladder that is disagreeable rather than painful.

A further characteristic that he is likely to have recognized for a long time is that of rank foulness of the decomposed urine. It is in many instances so bad that it is the chief cause for complaint.

This, of course, is due to the retention, infection, and decomposition of the urine stagnated in the sac which has no capability of evacuating itself, no matter how forceful the vesical detrusors may be contracting. It resembles a stagnant pool of water, and becomes as foul.

On examination residual urine is found usually in considerable quantity, but instead of the bladder readily emptying itself through the catheter, as is done in ordinary obstructive cases, the flow may be slow and sluggish, hesitant and with remissions, requiring suprapubic pressure to assist in evacuation. The bladder is not readily cleansed, repeated washings being required to obtain a clear return flow. The infected and inflamed bladder is unresponsive to treatment, both local

and internal, even though applied assiduously and with frequent relief of obstruction and retention.

In the face of such symptoms one should not fail to investigate the possibility of a diverticulum, single or multiple.

The orifice of a diverticulum is most frequently seen in the posterior or lateral wall of the bladder, and is usually made apparent by the cystoscope; but occasionally the orifice is not so readily demonstrated, as happened in the following case:

Fig. 408.—*x*-Ray Picture Showing Large Vesical Diverticulum Connected with Bladder Cavity by Narrow Neck.

Cavity from which prostate has been removed is also evident. Case noted on page 514.

A patient aged seventy-three underwent suprapubic prostatectomy, most efficiently done by a capable surgeon, who, however, did not make a cystoscopic examination before operating. The suprapubic wound healed in due time, but the symptoms of infection and inflammation, disturbed urination, etc., continued, and even grew more intense as time passed. The urine at the time of our first conference was about the most foul smelling that I ever encountered.

Cystoscopic examination disclosed the orifice of a diverticulum in the upper and *anterior* segment of the bladder on the right side; and a radiogram with 15 per cent. sodium iodid solution (Fig. 408) made a clear demonstration of the extraneous cavity, fully as large as the original cavity of the bladder. This explained the whole situation. Operative removal of the sac was followed by prompt and complete recovery, with relief from all symptoms.

Operative Treatment.—The steps of the operation practised by the author are based on those described by Lower, who deserves commenda-

tion for the work he has done in this field. If the cystoscope has shown the diverticulum as liable to involve the ureter or its orifice, it is advisable to catheterize this ureter before opening the bladder, tying the catheter in and well up the ureter. This renders the ureter easy of identification at any stage of the operation, and also gives protection against inadvertent wounding or cutting of it.

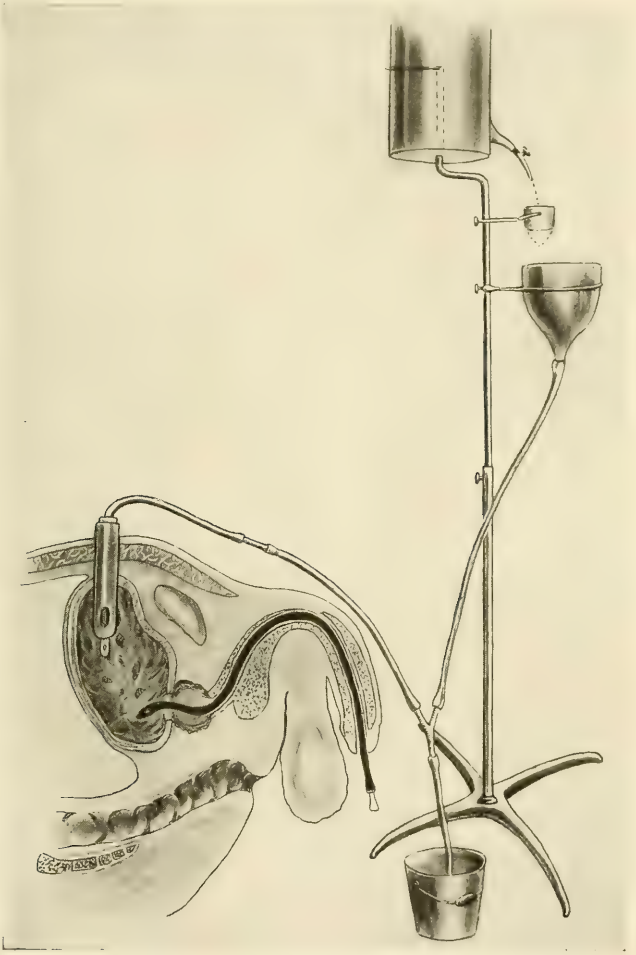

Fig. 409.—Suction Drainage Apparatus of Dr. L. W. Bremerman.

It is wise to keep the operation extraperitoneal, incising first into the bladder suprapubically. On emptying the organ the diverticular opening is detected by the finger and its depth and direction are determined. The bladder wall is sutured to the abdominal wall. The diverticulum cavity is packed tightly with long gauze strips until converted into a solid tumor. The process is materially expedited by having an assistant hold the margins of the orifice with forceps while the packing is done with

dressing forceps. After this the peritoneum is stripped back from the bladder and the diverticulum, releasing the latter from its bed of cellular tissues and permitting it to be held up as a pear-shaped solid body. It is cut from the bladder at the narrowest part of the neck and close to the bladder wall. The resulting opening is sewed until water-tight with successive rows of chromic catgut. If the ureter has been cut, its end is slit and drawn through a buttonhole in the bladder wall, where it is attached with fine catgut. Search is made for a possible obstruction to the urinary outlet—enlarged prostate, contracture at the vesical neck, urethral stricture, etc.—and any such obstructing factor is thoroughly relieved by appropriate operation.

While some operators utilize the incision through the anterior bladder wall for postoperative drainage, the author considers it preferable to sew this up tight and effect drainage in the following manner: (*a*) Drain the bladder by in-dwelling catheter in the urethra, reinforced if possible by a Bremerman apparatus (Fig. 409). (*b*) Drain the cavity from which the diverticulum was removed by a stab-wound and cigarette drain through the abdominal wall, 2 inches from the median line. This latter drain is to be removed in successive stages by daily shortenings and the opening is permitted to heal in five to eight days. (In some cases no urine drains through this route after three to five days.) The median abdominal wound is sewed up tight with silkworm-gut or chromatized catgut.

Postoperative irrigations are limited to the mere keeping of the in-dwelling catheter cleared.

The results of this mode of treatment are exceedingly satisfactory. Even though the diverticulum be located under the base of the bladder, it is still accessible to operation by the above method.

TUMORS OF THE BLADDER

Since the appearance of Vol. IV of this work the chief progress that has been made with reference to tumors of the bladder has related to treatment.

Prior to that time the treatment even of benign tumors was unsatisfactory and the results uncertain. Open operations as then practised were frequently followed by return of the growths or multiplication of them through inoculation in the course of operations. The results of Nitze's cystoscopic operating were far superior and more enduring.

In 1910 Edwin Beer submitted the plan of treating benign vesical tumors with the high-frequency electric current, which has proved so efficient that it has practically supplanted all other means and methods. It is easy of application (through the cystoscope); its effects are prompt and lasting, shrinking the tumor and causing its disappearance in a surprising manner, and even without sending the patient to bed. In every particular it has won the esteem of the profession as related to benign tumors.

With regard to malignant tumors of the bladder its position is not so clear. While it has seemed to assist in the eradication of certain carcinomata (especially the less infiltrating ones or those inclined to pedunculation), it has failed to benefit others, so that with respect to carcinoma it must still occupy a position of secondary importance.

On the other hand, two other methods of treatment have been developed in the period mentioned that have proved efficient in a number of cases, even of inoperable carcinomata, and have brought about restoration under most unpromising conditions. These are radiotherapy: (1) the local application of radium element or emanations; (2) the shooting of the tumor and its neighboring tissues with deeply penetrating *x*-rays of high voltage, as described by Pfahler.[10] By those who have had personal experience with these three methods it is considered advisable where possible to use all three of them in inoperable cases; or at least two of them (radium and *x*-rays) in the operable cases, following surgical removal as far as possible of all involved tissues. Metastatic growths are to be treated in the same way and as early after recognition as possible.

With respect to radium and the *x*-ray the beneficial effects depend on the exceeding sensitiveness of the pathologic cells to those influences, by which the epithelioma undergoes degeneration and melts away, while the healthier surrounding tissues may show no more effect than a little redness (Pfahler). The same author describes the effects of fulguration as consisting in the destruction of malignant disease by coagulation produced by the heat generated in the tissues because of the resistance to the flow of the electric current. The term is used synonymously with diathermy and electrocoagulation, but fulguration has been more generally adopted.

Fulguration.—The high-frequency current is developed by an apparatus especially built for that purpose; and either the monopolar current of Oudin or the bipolar current of d'Arsonval is utilized to obtain the fulgurating effect. The application is made in the following manner: An insulated wire electrode is passed through the catheterizing cystoscope and its exposed metal extremity is brought into contact with the tumor or its pedicle. The outer end of the electrode is connected with the wire from the apparatus and is controlled by a switch under the foot of the operator. If the d'Arsonval current is used (and it is the one most widely favored at present, giving greater penetration and being more easily controlled) a second wire connects the apparatus with a large wet pad placed on the abdomen of the patient. A small spark at first is advisable—$\frac{1}{8}$ or $\frac{1}{4}$ inch in length. The cystoscope itself is preferably connected for lighting with a dry-cell battery so that no short-circuiting may occur through it and the patient or the operator.*

* W. A. Phillips, of St. Louis, has made for me a converter wound in two independent coils, protecting against short-circuiting and permitting both connections with the street current.

Delivery of the spark into the tumor is indicated by active bubbling at the end of the electrode. The application is made at several different points of the tumor. The spark is interrupted at half-minute intervals, and may be repeated a half-dozen or more times. The séances may be held at intervals of five to seven days, according to the sensitiveness or the reactions on the part of the patient.

Ample local anesthesia must be provided for, as described on pages 502 and 503. (*Vide* also Clark's chapter on Electrical Methods in Surgery, Keen's Surgery, Vols. VI and VIII.)

Radiotherapy.—Experience has shown that the effect of radium is much more intense when brought into close proximity to the tumor than when placed at a distance from it. For that reason it is desirable to place the radium in contact with the tumor under observation through a cystoscope; or encased in its filtering capsule that is welded to a silver wire (Fig. 376), it is covered with a black rubber sheath and inserted into the bladder like a sound, the curve of the wire serving to control its location. This apparatus[1] is fairly comfortable, and with the assistance of a sedative is easily borne for the eight or ten hours required for the application. The patient urinates alongside the instrument as often as necessary; but a small amount of fluid should be left in the bladder to avoid too close a contact with the healthy membrane; 25, 50, or 100 milligrams of the element are used at a time; and the séance is repeated from two to five times, according to individual requirements.

Young adopts a different plan in the use of radium. He encases it in a cystoscopic applicator that is used from one to two hours at a time. This doubtless makes a more perfect localization of the element, but must be borne with difficulty in many cases.

Formerly, especially in carcinomatous prostatic cases, radium was applied also in the rectum, but so many and severe radium burns resulted that this has been largely discontinued. Another mode of applying radium is in the form of radio-activity embodied in fine glass needles which are inserted into pathologic tissues for a certain number of hours (Barringer) or abandoned there altogether for a more prolonged effect (Kelly and Burnham).

It is generally agreed that where a malignant tumor is infiltrating it should, if possible, be removed by an open operation and resection of the whole thickness of the wall of the bladder, embracing all of the tumor. In order to insure against the recurrence radium applications may be made in considerable strength and with exactitude through the resulting suprapubic wound during convalescence.

Roentgenotherapy.—Pfahler in a number of admirable papers[10] has described his method of applying *x*-rays in the treatment of deep-lying carcinomata, as in the bladder.

Deeply penetrating rays must be provided, so that a very powerful apparatus is required. A Coolidge tube is utilized. The apparatus must be capable of giving an output of large quantity of current, especially with a high degree of voltage. Extensive filtration of the rays

must be provided for reducing the rays that affect the skin. A vital feature of the technic is the extensive cross-firing in administering the treatments. Thus the neoplasm is attacked from every possible angle, especially through its deeper portions.

Ample protection must be afforded the skin against *x*-ray burns. This is accomplished through the softness of the tube, and further by dividing the skin into a number of squares and avoiding repetitions of the application on the same areas.

Treatments are given at three-week intervals; and some four or five days are necessary to finish the series.

Results.—While it must be admitted that failures still occur notwithstanding the use of these modern methods for the relief of vesical cancer, on the other hand, it cannot be denied that many instances are on record of recovery from conditions that seemed absolutely deplorable and unpromising. Such fortunate results have been reported by many reliable observers, supported by irrefutable evidence, so that the present outlook seems more promising than at any time in the past.

An illustrative case is the following:

Mrs. J. H. C., age fifty-four, was referred to me on April 5, 1917. She was emaciated, cachectic, debilitated, and harassed with frequent and usually ineffectual attempts at urination caused by obstruction from a definitely carcinomatous tumor (villous papilloma, according to the pathologic report of Dr. Ralph Thompson), about the size of a walnut attached to the left wall of the bladder, covering that part of the bladder including the left ureteral orifice.

Following treatments by electric fulguration (bipolar current) and two applications of 50 milligrams of radium element in April and July, there was appreciable improvement in both general health and local conditions. Cystoscopy August 3d following showed that a small ulcerated area was all there was to show for the former tumor. October 26th the vesical mucosa was seen to be absolutely clear of tumor or ulceration. The urine then was perfectly clear and evacuated in normal frequency. The general condition of the patient had improved proportionately and apparently there had been complete restoration physically. Weight had increased 15 pounds and the patient was an optimist instead of a misanthrope. A late report from her is to the effect that "she is in the best of health and absolutely normal in regard to her bladder condition." This report was May, 1919.

Another patient, male, nearly eighty, operated on suprapubically four years ago for carcinomatous prostate and subsequently treated with radium, *x*-rays, and fulguration is still in excellent condition—much better than three or four years ago; shows no evidence of the recurrence of the growth, urinates well, emptying the bladder each time, and claims good general health. He has had attacks of neuralgic (sciatic) pains at various times, which are invariably benefited by a series of *x*-rays.

CARCINOMATOUS PAPILLOMA. RECOVERY

Mrs. W. T. P., age fifty-three, was referred to me on September 30, 1918.

General condition very bad, emaciated, cachectic. Decline began a year previously. Bloody urine occasionally during past six months. Patient extremely nervous, almost hysteric at times, evidently showing toxic absorption from the condition we found in the bladder. Cystoscopy showed a large cauliflower-like growth from the left wall of the bladder; somewhat sessile in its attachment, and apparently $2\frac{1}{2}$ inches in diameter. Sections taken by forceps proved definitely carcinomatous (Ralph Thompson).

The treatment was in successive steps of fulguration, radium, and deep *x*-rays. December 3d following material improvement was manifest; the tumor had diminished to the size of a hazelnut. The patient's general health was greatly improved, strength, appetite, and mental condition distinctly better.

April 18, 1919 the tumor had entirely disappeared, leaving a cicatricial base only. Dismissed from further inspections. Last report, by personal conference, October 17, 1919, patient showed herself in perfect health, urine clear, apparently complete restoration.

SUPRAPUBIC CYSTOTOMY UNDER LOCAL ANESTHESIA

The material advantages accruing to the performance of suprapubic cystotomy under local anesthesia have made themselves apparent in connection with the more numerous operations done on prostates and bladders of the aged and the seriously debilitated of late years. It has been shown that under some form of local anesthesia the bladder can thus be opened readily for the removal of stone or foreign body, or for securing drainage, or for executing the first stage of a two-stage prostatectomy, a procedure that has latterly increased much in popularity, and chiefly because of the increased safety it conveys.

Following the use of this method there is no shock or disturbance of the alimentary tract, prominent and effective sources of depression, the importance of which is multiplied many fold in the aged individual already worn and depleted from the harassments of urinary obstruction, sepsis, etc.

Preceded a half-hour by a hypodermic of morphin and atropin or an H.-M.-C. tablet, the patient receives a final washing of the bladder on the operating table; 8 or 10 ounces of sterile water are left in the bladder for distention, the catheter being retained by adhesive strips over the penis and catheter. Unless precluded by the presence of asthma, cardiac disturbance, or adiposity the Trendelenburg posture may be employed in moderate degree. It is not necessary or advisable to distend the rectum for further elevation of the bladder.

The fluid most frequently used for producing local anesthesia is $\frac{1}{2}$ to 1 per cent. solution of procain (formerly novocain) in water, or normal salt solution. It is sometimes serviceable to add a drop of

1 : 1000 adrenalin to each ounce of procain solution, to make the effect more lasting.

With a sterilizable piston-syringe and a strong though slender needle 2 inches in length the fluid is injected in the median line of the suprapubic area for a space of 4 or 5 inches. The first injection should be intracutaneous rather than subcutaneous; and should show a linear wheal, as illustrated in Fig. 410. Thorough infiltration means instantaneous anesthesia, so the incision may be begun immediately, incising only as deeply as the infiltration. This must precede every incision. Any complaint of pain on the part of the patient means deficient and unsatisfactory anesthesia demanding correction.

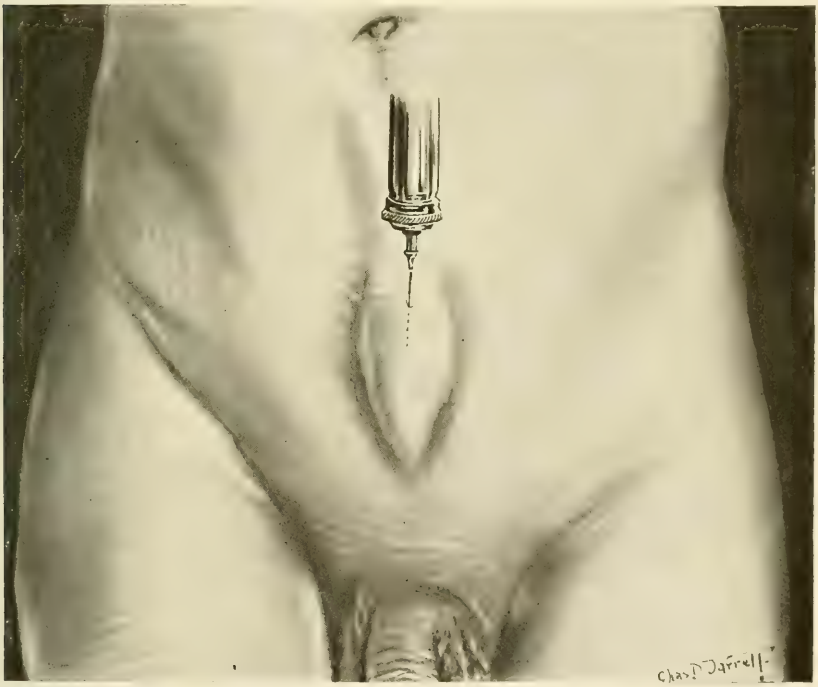

FIG. 410.—SUPRAPUBIC CYSTOTOMY UNDER LOCAL ANESTHESIA: APPLICATION OF INFILTRATION (SCHLEICH) ANESTHESIA PRELIMINARY TO THE SKIN INCISION.

On reaching the loose connective tissues of the prevesical space of Retzius the knife is laid aside (Fig. 411). Preceded by liberal injections of anesthetic fluid and with rather superficial retractors holding back the rectus muscles on each side, the lowermost fold of peritoneum is identified and pushed upward off the bladder by means of gauze-covered fingers of the operator (Fig. 412). It is preferably carried well up toward the vertex, where it is held by a third retractor protected with gauze.

Diffused injections of anesthetic fluid are made in the anterior bladder wall, now well exposed (Fig. 412). Three fixation sutures of twenty-day chromatized catgut are now placed as follows: The first is passed through the fascia and the rectus muscle of one side, entering the

vesical wall ¾ inch from the median line, and is directed downward for ¾ inch; emerging, it is again passed through the fascia and the rectus of the same side (Fig. 413). A similar suture is placed on the opposite side; and a third one, running cross-wise from rectus to rectus and engaging the vesical wall at the vertex (Fig. 413), just below the peritoneal fold, provides for firm fixation and application of the wall of the bladder against the abdominal wall. The sutures are not yet tied, but are grasped by forceps. Attaching a long rubber tube to the catheter remaining in the urethra, the contents of the bladder are permitted to syphon out, completely emptying the bladder.

Fig. 411.—Exposure of Prevesical Tissues Preliminary to the Identification of the Lower Peritoneal Fold.

With two lateral fixation sutures as anchors, the bladder is punctured in the median line with a narrow-bladed bistoury. This evacuation of the bladder prevents the unnecessary flooding of the wound and the field is practically a dry one. The lateral sutures are tied and future separation of the bladder from the abdominal wall is impossible, protecting materially against subsequent diffused infection or suppuration in what has many times proved dangerous territory.

Following any desired manipulations in the bladder (removal of stone; palpation of prostate, etc.) a rubber tube of appropriate dimensions is inserted suprapubically and held in place by tying the long ends of the fixation sutures around it. The third fixation suture (*c*) is also

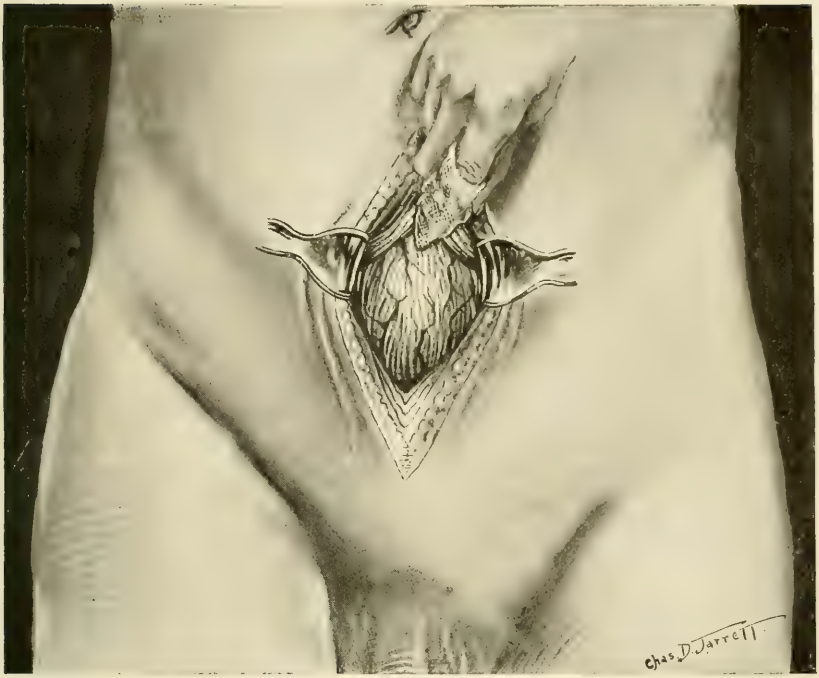

FIG. 412.—IDENTIFICATION AND SEPARATION OF THE LOWER FOLD OF PERITONEUM BY MEANS OF THE GAUZE-COVERED FINGER; DEFINITE EXPOSURE OF THE BLADDER WALL.

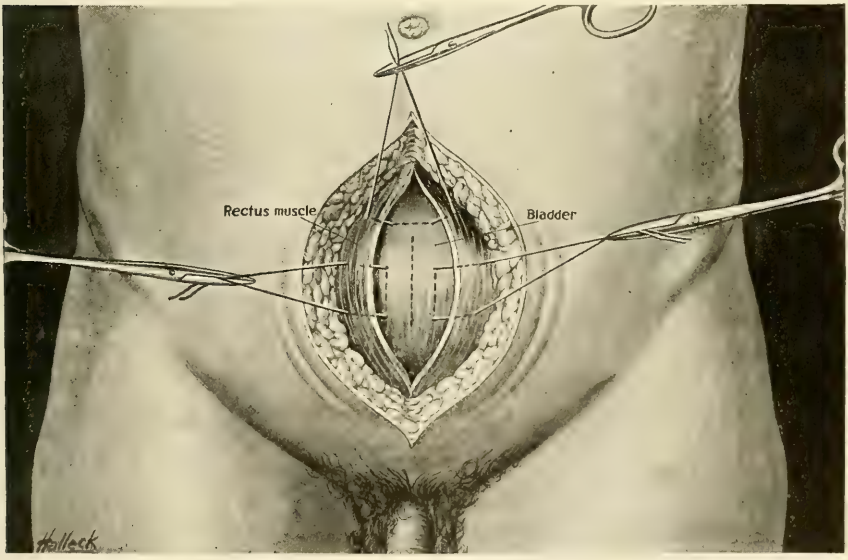

FIG. 413.—APPLICATION OF FIXATION SUTURES PRIOR TO OPENING THE BLADDER.

tied. The cutaneous wound is closed with silkworm-gut sutures. A small piece of rubber or a cigarette drain is left to take care of drainage in the prevesical space for a day or two. The sutures in the skin must not be tied too tightly, else infection will be invited.

In anticipation of the subsequent removal of the prostate (second stage) it is desirable to have the vesical drainage-tube previously mentioned of large diameter (Marion tube $\frac{3}{4}$ to 1 inch) for providing better access to the bladder at the second operation. Drainage may be favored by establishing syphonage through a long rubber tube leading into a bottle; or if a small leak of air prevents syphonage the accumulating urine may be intermittently aspirated and drained by means of the Bremerman apparatus (Fig 409), which is of gratifying assistance in many cases.

If prolonged drainage is not desired, the larger suprapubic tube may be replaced with a smaller one on the second or third postoperative day; and shortly after that dependence may be placed on an in-dwelling urethral catheter following the removal of the suprapubic tube. The aspirating apparatus may be used, if desired, in connection with the urethral drainage as well. This usually expedites the closing of the suprapubic wound.

URETERAL TRANSPLANTATION

Conditions are occasionally met with in which it is necessary either to remove the bladder (cystectomy), as in some of the radical operations for exstrophy, or while retaining it, as in inoperable carcinoma, to dispense with its services as a urinary reservoir and divert the urine in some other direction. The incessant sufferings of the patient in some carcinomatous cases become uncontrollable even by heroic doses of opium, and nothing short of diverting the urine stream offers relief. The question then arises as to the best method of diversion.

Watson[11] advised ligation of the ureters and nephrostomy, draining directly from the kidneys into receptacles strapped tightly to the loins. Others after ligating the ureters have stitched the ends of their upper segments into the loins, maintaining permanent drainage in that locality. Experience with these methods has developed serious objections to both, relating chiefly to the difficulty of controlling the drainage, urinary odor, etc.

The several advantages pertaining to transplantation of the ureters into the lower bowel, if made safe and practicable, are obvious.

It has been established long since that under such circumstances the lower bowel readily accommodates itself to the presence and retention of urine for a reasonable length of time, say two or three (in some cases five) hours; so that objection from this source is not to be expected. But early operations of this sort were followed by ascending infections from bowel to ureter and kidney, with death from infectious nephritis. The earlier operations were, however, defective in omitting to secure a valvular effect for the ureteral orifices. The later operations have

largely overcome this objection, and results have become much more satisfactory.*

Lower[13] has reported favorably on the use of this method in 4 cases, in 2 of which the transplantation was followed by the removal of carcinomatous bladders, with relief for two and a half years, and at least six months, respectively. In the other 2 cases (in which conditions were so bad that the bladders were not removed) there was a relief from the

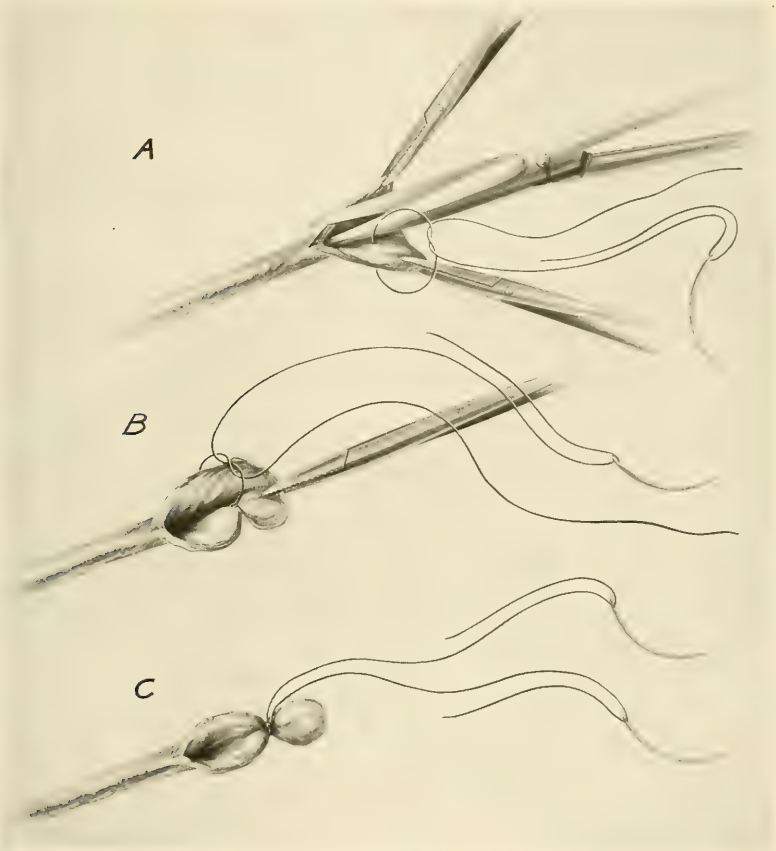

FIG. 414.—STEPS IN COFFEY'S OPERATION OF URETERAL ANASTOMOSIS WITH THE BOWEL. (Courtesy of Dr. Robert C. Coffey.)

excruciating pains that had prevailed, fully justifying the procedure, in the opinion of Lower.

The methods of transplantation most generally approved are those of Coffey,[14] Martin,[15] and Maydl.[16]

* Illustrating the tolerance of the rectum in accommodating itself to the presence of urine may be mentioned a remarkable case of Dr. W. W. Keen.[12] In this case after a number of unsuccessful operations for the closure of vesicovaginal and rectovaginal fistulæ had been done, Dr. Keen permanently closed the vaginal outlet, after which for thirty-five years the patient urinated and defecated, and for eleven years menstruated by way of the rectum.

Coffey's Operation.—The essential and vital feature of this operation is that the ureteral implantation is made *submucous;* not buried in the muscular layers of the gut, as in Martin's technic, nor superimposed on the peritoneum, as in Stiles' technic. Coffey claims that his method affords protection against ascending infection by giving *intra-intestinal pressure* through the mucosa, accomplishing true physiologic valvular closure against regurgitation or entrance of bacteria into the ureter.

Of 9 dogs operated on by Coffey in this way, 5 recovered, and no evidence of ascending infection was shown in them—a most excellent showing as compared with the results of other methods.

The technic is described as follows: First the ureter is located and ligated with linen or silk. It is then cut into above the ligature and the

Fig. 415.—Incision Through Serous Coat of Bowel.

edges caught and held with mosquito forceps, while one wall is split down with a pair of scissors, as in Fig. 414, *A*. A linen suture is now passed through the split end of the ureter so as to include about half of it, and tied (Fig. 414, *B*). The loose ends are then threaded into two needles. By this method the full strength of the ureter is retained for traction, while the opening is maintained by the split (Fig. 414, *C*). The end of the ureter is now wrapped with gauze, while the intestine is prepared for its reception, which is done as follows:

"The part of the intestine desired is picked up and an incision made down through the peritoneal and muscular coats, including submucous tissue. The muscular layer is loosened from the mucosa with the point of the knife until the mucous membrane pouts out through the incision (Fig. 415). This incision should be about 1 inch long or more. Sec-

ond, five or six sutures are passed which pick up the peritoneal and muscular coats on each side of the incision (Fig. 416). The suture at the upper end of the incision is tied as a control suture. The intermediate intestinal sutures are lifted up on the flat handle of an instrument as they cross the incision. Now the intestine is brought down close to the split ureter and the two needles carrying the threads (traction sutures) on the end of the ureter are passed beneath the four or five intestinal sutures and through the stab wound in the mucous membrane into the intestinal lumen and out through the intestinal wall $\frac{3}{4}$ inch farther along the intestine, and $\frac{1}{8}$ to $\frac{1}{4}$ inch apart. By making tension on these threads and at the same time pushing the intestine toward the ureter the latter is drawn beneath the intestinal sutures through the stab-wound into

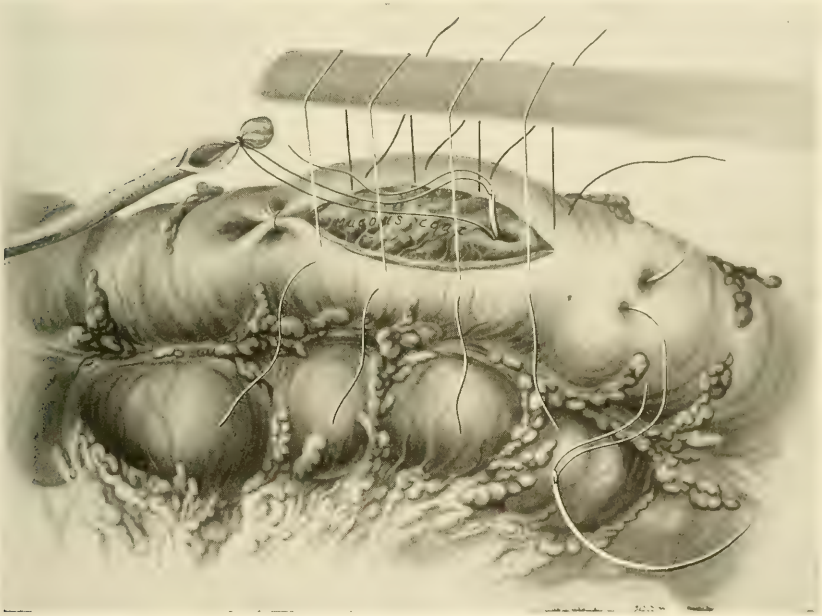

Fig. 416.—Application of Sutures.

the intestinal lumen (Fig. 417). The two ends of the threads on the ureter are tied on the outside, thus anchoring its ends on the inside of the intestine at this point. The intestinal sutures are then tied, producing the result shown in Figs. 417, 418. After this operation the ureter lies just beneath the mucous membrane, which has been loosened for approximately $\frac{3}{4}$ inch of its course, so that it slides easily in its new channel. It is therefore necessary to tack the ureter to the peritoneum of the intestine near its point of entrance by two or three fine linen or silk blood-vessel sutures. Care should be used to take only the outer coat of the ureter in the site of these sutures. Thus practically all of the steps of the operation are completed before the intestinal mucosa is penetrated, and no sutures penetrate the lumen of the ureter.

The traction suture at the end of the ureter within the intestine and the two or three anchor sutures fastening the duct to the intestinal peritoneum are the only means of retaining the ureter in place."

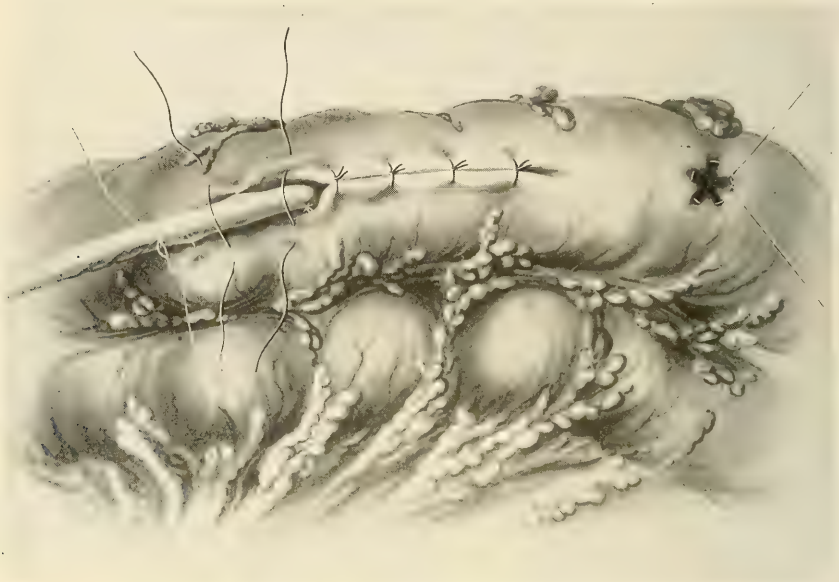

FIG. 417.—INSERTION AND SUBMUCOUS IMPLANTATION OF URETER.

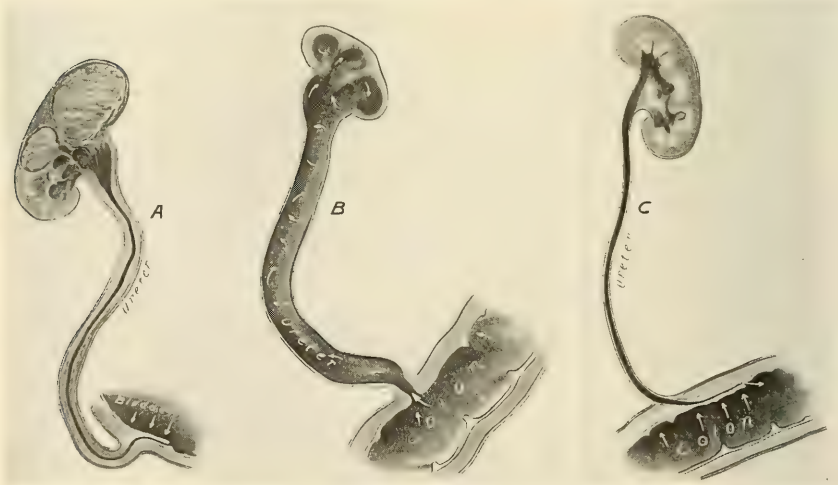

FIG. 418.—THE MODUS OPERANDI OF "ASCENDING INFECTION."

A. What probably happens in experiments where infection is injected around the ureter near the bladder; a true ascending infection following the lymphatics. *B*, Dead kidney; dilated ureter following direct implantation of the ureter into the colon. This result has usually been referred to as "ascending infection." It is more probable that the kidney has been destroyed and the ureter dilated by intra-intestinal pressure applied inside the ureter. *C*, Normal kidney and undilated ureter which follow the submucous or indirect implantation of the ureter into the colon. (Coffey.)

The operations of Coffey and Martin are carried out in successive stages, the first involving the transplantation of one ureter; within two

or three weeks, according to the patient's progress, the second ureter is operated on, and if the cystectomy is done it is undertaken after three or four weeks' interval or when the patient has recovered sufficiently.

In **Maydl's operation** the whole trigone is dissected out from the remainder of the bladder, with the ureteral orifices intact; this segment is then transplanted into the wall of the sigmoid, thus retaining the natural valvular effect of the ureteral orifices, and obviating the necessity of dividing this part of the procedure into two stages.

Obviously this operation is likely to be more appropriate for exstrophy than for vesical carcinoma. (For discussion of exstrophy operations, see Vol. IV, Keen's Surgery, page 298.)

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CHAPTER XLVIII

SURGERY OF THE PROSTATE*

By Hugh H. Young, M. D.,

Baltimore

Cysts of the Prostate at the Vesical Orifice.—The subject of cysts of the prostate was treated in Vol. IV (1906). The important communication of English on Cysts of the Colliculus was referred to and mention was made of cysts causing obstruction to urination at the prostate orifice, but no case in which operative removal had been carried out was found in the literature.

Fig. 419.—Illustration Showing Position of Cyst at the Vesical Orifice.

Note the pedicle springing from the posterior urethra just posterior to the verumontanum, the cyst extending through the vesical orifice into the bladder.

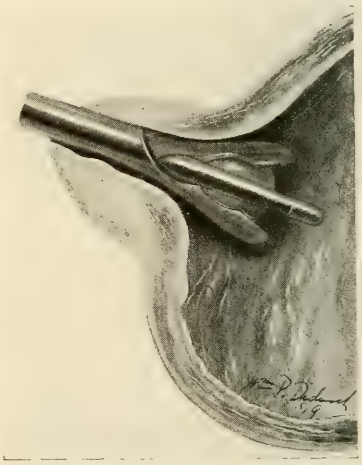

Fig. 420.—Removal of Cyst at Prostatic Orifice with Young's Cystoscopic Rongeur.

In Vol. VI (1912) I detailed at length the case of a young man with a cyst 2 cm. in diameter projecting into the bladder from the prostatic urethra and causing obstruction to urination, which was removed by my cystoscopic rongeur. This and other cases operated on by this instrument were cited in a paper before the Medical and Chirurgical Faculty of Maryland in 1912.

Recently, with the assistance of R. H. Van Denburg, a very careful study of the literature and of our clinical records has been made.

*Supplementary to Chapter LIX, Vol. IV, p. 372, and Chapter CXXXV, Vol. VI, p. 670.

Stated in chronologic order the cases collected are as follows:

1. Abbe, 1900: The patient a male, aged thirty-five, with symptoms of acute retention one year before. A suprapubic cystotomy was performed and a tumor the size of a cherry was discovered at the upper wall of the internal orifice and the upper portion of the prostate, which acted as a ball valve. The cyst was transfixed by a hook, cut off, and the base sutured. The bladder was drained for a few days.

2. Burkhardt, 1902: A male, aged fifty-two, who had symptoms of frequency, seems to have been the first diagnosis made of a cyst at the prostatic orifice by the cystoscope. The cyst was destroyed by a suprapubic operation.

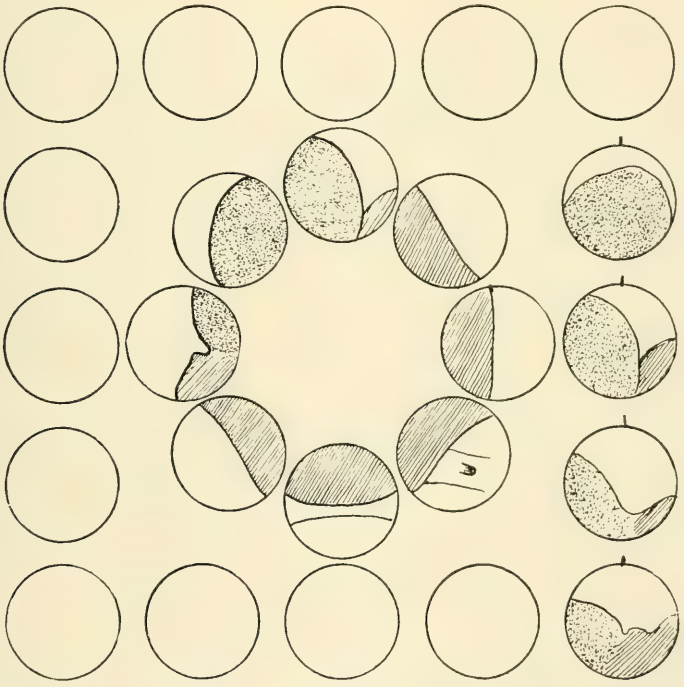

Fig. 421.—Cystoscopic Chart Showing the Cyst Projecting from the Right Anterolateral Aspect of the Prostatic Orifice.

3. A. Cabot, 1906: A male, aged forty-six, complained of frequent urination, and on one occasion acute retention. A suprapubic cystostomy was performed, the cyst grasped with a pair of sharp-edged forceps, ruptured, and its wall cut away with scissors. The patient recovered.

4. Young, 1912, was reported in Vol. VI, Keen's Surgery. Man aged forty years with symptoms of obstruction to urination in which the diagnosis of cyst at the prostatic orifice was made with the cystoscope (Fig. 419) and its removal accomplished at once with Young's cystoscopic rongeur under local novocain anesthesia (Fig. 420). This case was

interesting as being the first in which the cyst was removed without resort to a suprapubic operation.

5. Young, 1912: Male, aged forty-three (No. 3244), admitted June 11, 1912, with obstruction to urination, voiding urine every one to two hours night and day. Residual urine 45 c.c. Bladder capacity 200 c.c. Cystoscope showed a cyst at the prostatic orifice as seen in Fig. 421. A suprapubic operation was carried out to remove the calculi and at the same time the cyst was removed intact (see photo., Fig. 422).

6. Young, 1913: Male, aged thirty-five (No. 3187), admitted Dec. 12, 1913 with dysuria, difficulty and frequency for fourteen years. He urinated six to eight times every night. Rectal examination found a normal prostate. The cystoscope showed two cysts anteriorly, one on each side of the median line at the prostatic orifice. They were removed with the cystoscopic rongeur and a small median bar was excised with the "Punch" operation. There was considerable postoperative difficulty in evacuating the blood-clots from the bladder, and accordingly suprapubic drainage was provided six hours later. The patient made an excellent recovery and reported two years later that he was completely cured, urination being normal.

FIG. 422.—PHOTOGRAPH OF CYST AFTER IT HAD BEEN REMOVED, SHOWING ITS PRESERVATION INTACT (ACTUAL SIZE).

7. Ekehorn,[1] 1914: Male, aged fifty-four, complete retention of urine. The case seemed to be of the ordinary type of prostatic retention, although the prostate was not palpable. No attempt at cystoscopy was made. The bladder was opened by a suprapubic incision and a small round tumor on a long stem at the urethral orifice was found. This tumor had dropped into the funnel opening of the urethra and obstructed it like a ball-valve. It was easily pushed aside by the tip of the catheter. The man had been in the hospital for the same trouble twice before, in 1910 and 1911. Each time the retention came suddenly, and the patient was unable to void a drop of urine, although catheterization was done without difficulty. Then the ability to void urine returned as suddenly and as completely as before, and there was no further disturbance for another year. The cyst must have been ruptured by the catheter; and offered no further obstruction until it grew again, and again started its valve action. Cyst removed.

8. Lower, 1915*: Male, aged fifty-one. Difficult urination for eight years. After opening the bladder a cystic tumor, size of thumb, was seen protruding from the prostatic portion of the urethra into the bladder. The sac was removed.

9. Frontz, 1916: Male, aged forty-six. Frequency and difficulty of urination for one year. Operation: Perineal prostatectomy, removal of lateral and median portions of prostate, which showed chronic

* Ohio Med. Jour., xi, 430.

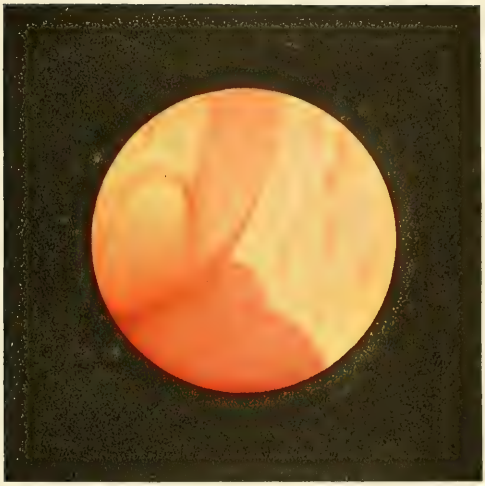

Fig. 423.—Cyst at Prostatic Orifice (Case 10).
Painting shows prostatic margin below, bladder (in distance) to the right, cyst above to the left.

prostatitis, but no adenomata. The cyst was ruptured, but was grasped with clamps and shelled out completely. It measured about 2 cm. in diameter. Convalescence uneventful.

10. Young, 1919: Male, aged forty-five. Frequency and difficulty of urination for one year. Cystoscopy: Residual 50 c.c.; B. B. 200 c.c.; globular translucent cyst at right anterolateral margin of the prostate (Fig. 423). Treatment: Wall of cyst was destroyed thoroughly by fulguration along inner inferior aspect, as graphically shown in Fig. 424. Cystoscopy one year later. No recurrence of cyst. Cured.

Analysis of Cases.—A collection of 9 cases is here presented—2 patents were thirty-five years of age; 4, between forty and forty-six, and 3, between fifty and fifty-five years. There was a history of gonorrhea in 4 cases (not noted in the others).

Chronic prostatitis was present in all my cases, but it is doubtful whether it had anything to do with the development of the cyst. In

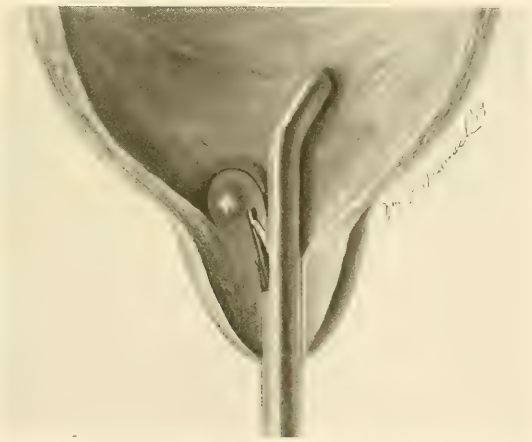

Fig. 424.—Destruction of Cyst by Fulguration in Case X.

one case symptoms of obstruction appeared during an acute gonorrhea fifteen years before. Sounds were passed and urination remained normal for three years, when the obstruction returned. It seems probable that the cyst was present and ruptured by the sound.

There are several cases in the literature where the passage of a catheter caused rupture of the cyst.

Prostatic hypertrophy, *i. e.*, adenoma, was absent in all of our cases, and was not definitely demonstrated in any of the others. Residual urine was noted in 7 cases as follows: 0, 45, 50, 200, 330, 500 c.c. and "complete retention." The bladder capacity was reduced in most cases (200 to 300 c.c.). The cyst lay within the prostatic orifice in all cases, and projected into the bladder, varying in size between 1 and 2 cm. It was attached to or sprang from the lateral wall near the anterior margin in all of my cases, right 4, left 2. In the other cases the description is not very definite, but in all cases the obstruction produced

was similar to that of an intravesically projecting prostatic lobe, in some cases "ball valve in type."

The diagnosis was made by the cystoscope from the translucency of the rounded mass, Burkhardt in Case II and in my 4 cases. No difficulty should be encountered if the pedunculated nature of the tumor is observed and care taken to test for translucency by drawing the lamp of the cystoscope up against the tumor and looking through the transilluminated mass.

As noted above, the operations carried out have been various, viz.: Suprapubic rupture of cyst and cutting away of portions of the wall. (Cases: Abbe, 1; Burkhardt, 2; A. Cabot, 3; Ekehorn, 7; Lower, 8. All with good result.)

Perineal rupture and removal with clamp and scissors after perineal prostatectomy 1 case; Frontz, 9; with excellent results.

Suprapubic removal of cyst intact by blunt dissection 1 case, Young, 5.

Removal of cyst through urethra with cystoscopic rongeur 2 cases, Young, 4 and 6.

Destruction of cyst wall by fulguration through cysto-urethroscope 1 case, Young, 10.

The mortailty after all operations is nil.

All of these procedures were successful, but the one which appears to be the simpler, and has the advantage that it can be done without general anesthesia and without hemorrhage or the postoperative use of an inlying catheter, is fulguration. It is not sufficient, however, to simply empty the sac by a linear fulguration, as the literature furnishes examples where cysts have recurred after rupture by catheter. The destruction with the high-frequency spark should be extensive, cover a wide area of the cyst wall, and possibly be repeated if cystoscopic observation shows cyst wall remnants which might cause recurrence.

Tuberculosis of the Prostate.—Recently attention has again been attracted to the unfavorable results in tuberculosis of the prostate and seminal vesicles with the conservative methods which have been employed in the past. For a long time it was held that castration or epididymectomy was alone sufficient to lead to the subsequent disappearance or cure of tuberculous processes in the prostate and seminal vesicles. Recent statistics of various clinics show that in many instances the tuberculosis of the prostate does not clear up, but progresses and ultimately leads to involvement of the bladder and upper urinary passages.

In recent papers by myself[2] the unsatisfactory results of conservative methods were brought forth, and a new radical operation for tuberculosis of the prostate and seminal vesicles was described as follows:

"It occurred to me in 1912 to use methods similar to my perineal prostatectomy for tuberculous seminal vesicles. One of the principal objections to previous operations through the perineum was the usual development of chronic urinary perineal fistulæ. In order to avoid this a tractor of smaller caliber and longer shaft was constructed which

could easily pass through the penile urethra into the bladder and thus be used for traction without opening the urethra through the perineum, as shown in the illustrations of Mr. Broedel demonstrating the development of this operative procedure.

The ordinary inverted **V** perineal incision which I have always employed for perineal prostatectomy has been found entirely satisfactory, and after division of the central tendon (Fig. 425) and recto-urethralis muscle, the membranous urethra and apex of the prostate are easily

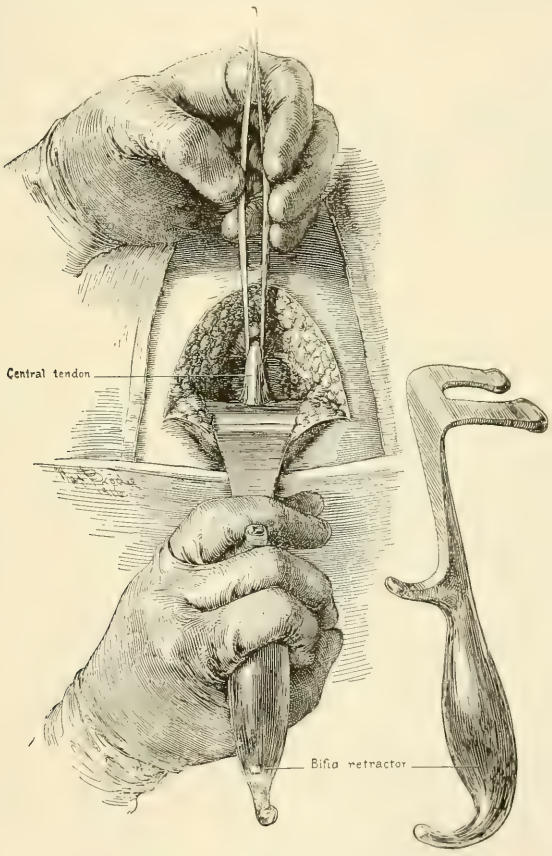

Fig. 425.—Central Tendon Put on Tension by Bifid Retractor Previous to Division.

exposed without cutting the levator ani muscles. Up to this point the tractor has been introduced only sufficiently far that its beak lies in the membranous urethra, thus giving an index as to its location. It is then carried into the bladder, opened out, traction made, and pressure employed (Fig. 426), thus by leverage forcing the prostate and seminal vesicles up into the wound where little difficulty is experienced in uncovering the fascia of Denonvillier, the anterior layer of which forms the covering of and index to the seminal vesicles and vasa deferen-

tia as well as the prostate. In this exposure the levator ani muscle is drawn outward and backward with the rectum, exposing the superficial or posterior layer of Denonvillier's fascia, which is divided near the apex of the prostate, thus uncovering the shining or deep layer of Denonvillier's fascia. The incision which must now be made through the fascia of Denonvillier in order to expose the vasa and seminal vesicles may vary somewhat according to the extent and character of the involvement,

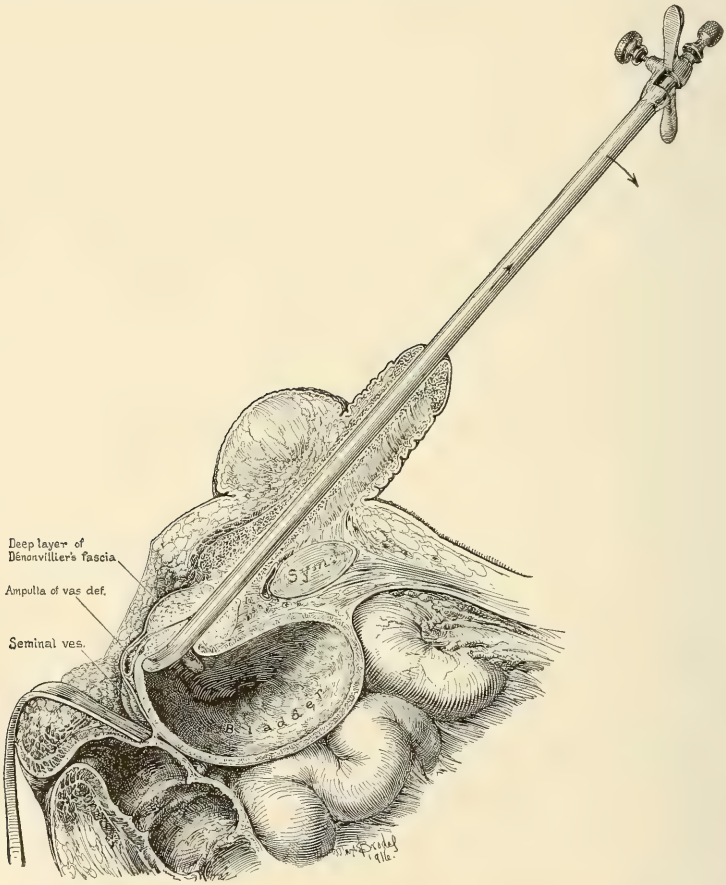

Fig. 426.—Traction and Leverage Made with Tractor Forcing Prostate and Seminal Vesicles into the Wound.

but as a rule a **Y**-shaped incision (Fig. 427) has been found most satisfactory for nearly all cases in which both seminal vesicles, ampullæ and lateral lobes of the prostate are involved. The fascia is then elevated on both sides, thus exposing the lateral lobes of the prostate, ampulla, and seminal vesicles, and leaving the central portion of the prostate (in which the ejaculatory ducts lie) immediately beneath the urethra intact and covered by fascia which aids in protecting them. An excellent exposure is thus obtained (Fig. 428) and it is possible to determine

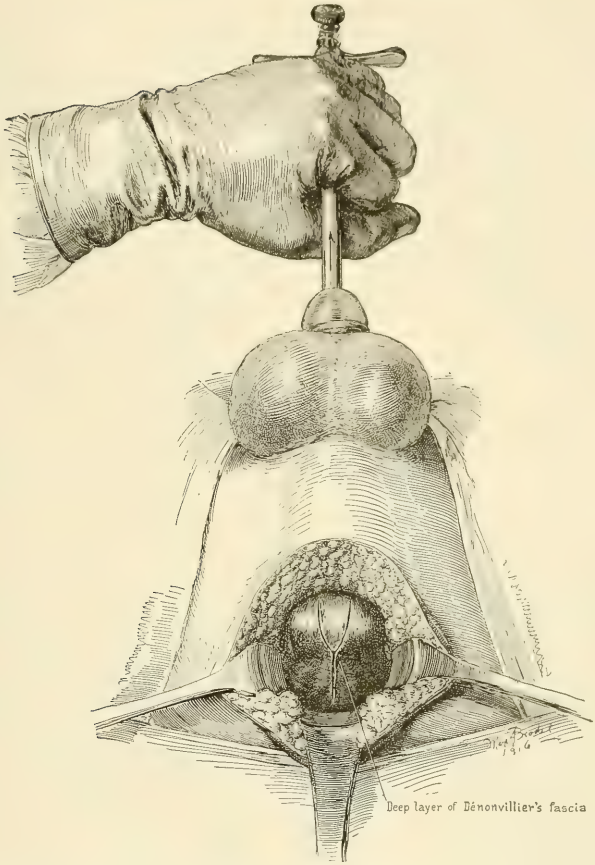

FIG. 427.—LEVATORS AND RECTUM DRAWN AWAY, EXPOSING FASCIA OF DENONVILLIER. Y-SHAPED INCISION THROUGH FASCIA.

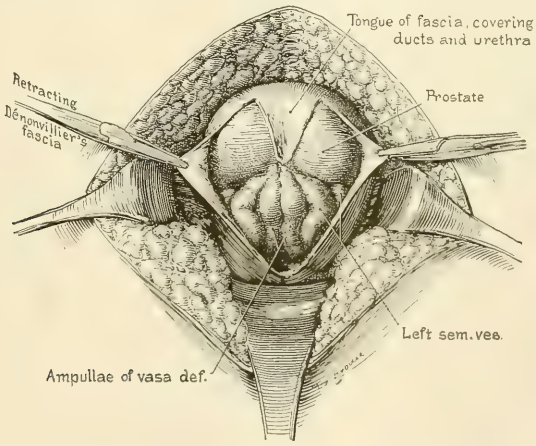

FIG. 428.—FASCIA OF DENONVILLIER ELEVATED BY BLUNT DISSECTOR EXPOSING LATERAL LOBES OF PROSTATE, SEMINAL VESICLES, AND VASA DEFERENTIA.

exactly how much should be removed, whether the disease is unilateral or bilateral, and whether one or both lobes of the prostate should be excised. Another advantage of this method is that the main blood-supply which lies externally is thus pushed outward with the fascia and hemorrhage is avoided, making it possible to see well and to carry out a delicate and accurate blunt dissection without injury of the bladder, to which the ampullæ and vesicles are often very adherent. The vas deferens should be freed well up toward the point where it winds around the ureter and then clamped and divided, the upper clamp being left attached to assist in removal of the upper portion of the vas deferens, in case epididymectomy or castration is contemplated. The

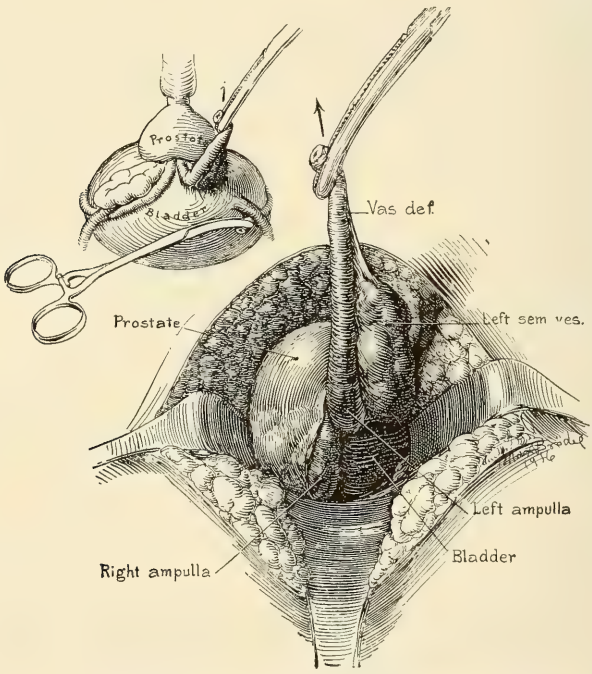

Fig. 429.—Left Seminal Vesicle Freed, Vas Divided Between Clamps.

seminal vesicle on this side is then freed, firm adhesions being clamped and ligated after division in order to prevent bleeding, and, working from above downward, the seminal vesicle and ampulla are freed until the junction with the upper portion of the prostate is reached (Fig. 429). If it seems desirable to remove a portion of the prostate, an incision is made parallel to and at a distance of 5 mm. from the urethra (and dividing the ejaculatory duct), but leaving sufficient tissue to avoid a urinary fistula (Fig. 430). After this the prostatic tissue is easily removed by enucleation from within its capsule, and the fascia, ampullæ, seminal vesicles, and lateral lobe of the prostate are thus removed in one piece. If the disease is bilateral the same procedure is carried out on the opposite side and the wound then partly closed, the long clamps

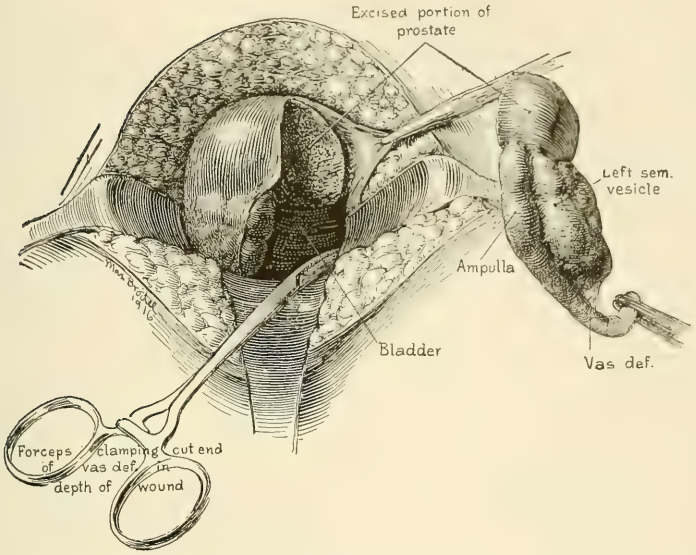

FIG. 430.—VAS, VESICLE, AND MOST OF LEFT LATERAL LOBE OF PROSTATE HAVE BEEN REMOVED IN ONE PIECE.

Note division of ejaculatory duct near urethra.

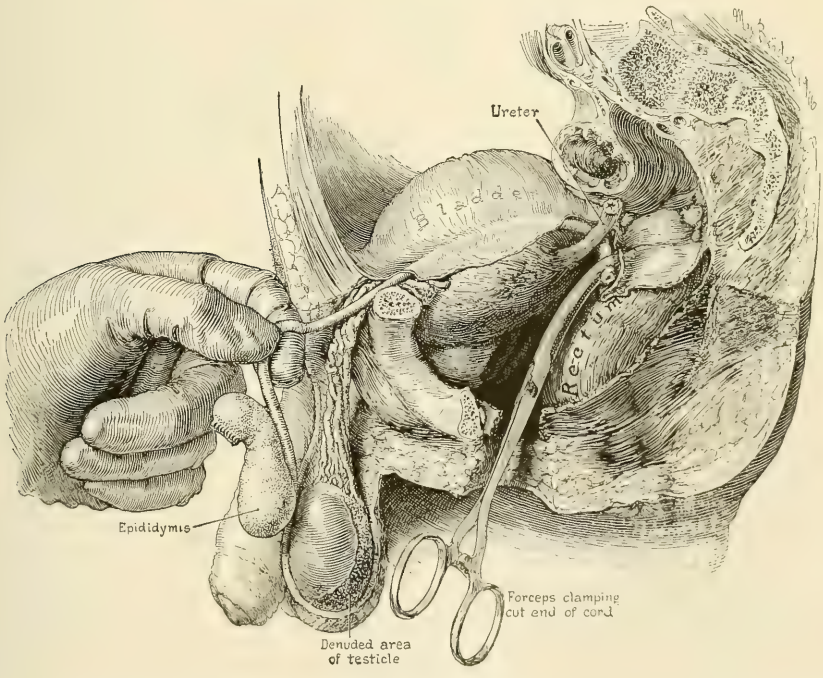

FIG. 431.—SHOWING METHOD OF TRACTION (ALTERNATING BETWEEN OPERATOR IN GROIN AND ASSISTANT PULLING ON CLAMP IN PERINEAL WOUND ON VAS) BY WHICH VAS IS FREED AND THEN DRAWN OUT THROUGH INGUINAL CANAL.

being left attached to the upper ends of the vasa deferentia for traction later. In this closure two iodoformized gauze drains are provided, the levator ani muscles are brought together, and the wound closed as in prostatectomy, leaving room for drainage. The patient is then placed on his back and epididymectomy or castration carried out according to the extent of the lesion present. This is also so well shown in illustrations that detailed description seems unnecessary.

The vas deferens, which has been exposed up to the external ring, is then freed from adhesions in its canal by a to-and-fro traction (Fig. 431), produced by an assistant pulling upon the clamp (which we mentioned above as being left upon the lower end of the vas deferens), alternating with traction by the operator upon the vas deferens in the

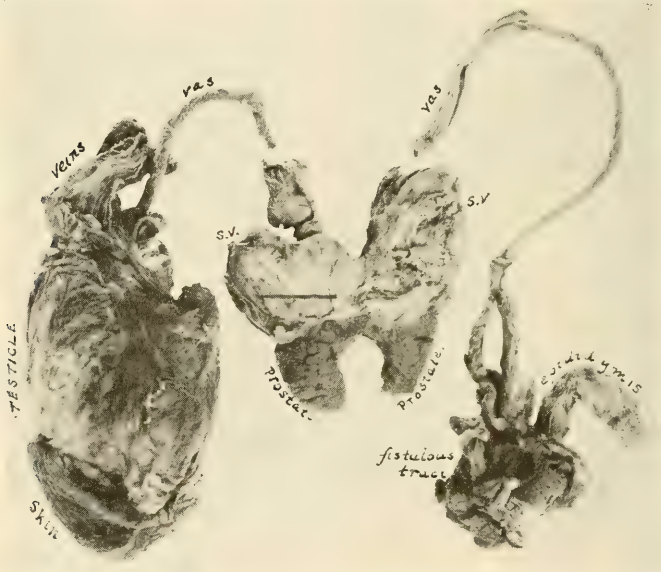

Fig. 432.—Photograph of Specimen Showing Removal of Both Vesicles, Vasa, and Lateral Lobes of Prostate; Median Portion and Urethra Preserved. Castration on One Side, Epididymectomy on Other.

groin. In this way the vas is easily drawn out in its entirety through the groin, as shown in the illustrations (Fig. 432). In this way we have a complete and radical removal of the entire seminal tract, with the exception of a few millimeters, the terminal portion of the ejaculatory duct, and we have also a conservative prostatectomy, leaving the urethra and bladder intact. This procedure, which is far more thorough and radical than any other which has been proposed, is carried out with great ease and is entirely under visual control.

It has long been shown that very satisfactory results were obtained by nephrectomy in tuberculosis of the upper urinary tract, but occasionally the tuberculous ureter, which cannot be excised in its entirety, gives trouble, and tuberculosis of the bladder sometimes persists. With this radical operation for tuberculosis of the seminal tract the

removal is more complete and the results even more satisfactory than with nephrectomy.

In a recent paper read before the Urological Section of the American Medical Association June, 1918, Quinby reports 7 cases in which he had used the operation above described with a few technical additions, with excellent results, and strongly advocated the use of radical operation in cases of genital tuberculosis in which the prostate and seminal vesicles were involved.

In the discussion which followed Barney stated that after epididymectomy or castration recurrence occurs on the opposite side in about 50 per cent. of the cases. This we have considered to be due to the involvement of the prostate and vesicles from the first epididymis. But after removal of the first epididymis the process in the prostate and seminal vesicles quiets down in about 50 per cent. In about 50 per cent. the process in the prostate or seminal vesicles does not subside before involvement of the second epididymis takes place. In cases where both epididymes have been taken out, with two or three exceptions, the prostate and vesicle which were previously tuberculous have quieted down to the extent that they are clinically cured.

In my clinic the series of cases is too limited and the time since operation too short to draw definite conclusions as to cure, but it has been sufficiently demonstrated that tuberculosis of the seminal vesicles can be completely removed with a satisfactorily large mass of each tuberculous lateral lobe of the prostate through the perineum without the development of urinary fistula, and with apparent cure. In view of the number of very unsatisfactory results obtained by other methods I am inclined to advocate as a much more routine procedure radical removal of all the seminal tract involved in tuberculosis as carried out in the operation above described.

Rôle of the Prostate in General Toxemias.—It is now becoming more and more generally recognized that the etiology of many obscure joint, cardiac, neurologic, and obscure diseases is to be found in chronic infections in remote organs. In recent years the mouth, nasopharnyx, and alimentary tract have come to be regarded as most frequent sites of such focal infections. The extent to which the genito-urinary tract is to blame has not been appreciated, and in reviewing the literature one finds very valuable articles giving exact data on this question.

The frequency of acute prostatitis and seminal vesiculitis is well recognized. The fact that in the majority of cases of gonorrhea the posterior urethra, prostate, and vesicles become involved is well known, but the profession fails to realize, or perhaps neglects the fact that chronic prostatitis and seminal vesiculitis are extremely common diseases, and that they may exist without producing symptoms or attracting the attention of the patient for years, only to show themselves as a danger seat when the patient marries or becomes the subject of chronic rheumatism or other forms of remote infection and toxemia arising from an old prostatitis or vesiculitis.

Owing to the fact that all these structures drain badly, being depen-

dent on minute tortuous ducts and tubules (Fig. 433), foci of chronic inflammatory infiltration remain unrelieved for years, often become surrounded by fibrous changes, and remain centers for the absorption of toxins and infections, and sources of local irritation, pain, and discomfort.

Symptoms.—The symptoms of chronic prostatitis and seminal vesiculitis may briefly be classed as local, urinary, sexual, nervous, and general.

The local symptoms are often so slight (merely a little discomfort, fulness, or heaviness) that it is most often the sexual changes which bring the patient for treatment.

The nervous symptoms are often so remote and disconnected that the prostate is not suspected. I have seen many cases of lumbago, sciatica, vague pains in the back, perineum, groin, hips, thighs, and often as far as the soles of the feet, caused by chronic inflammations of the prostate and seminal vesicles.

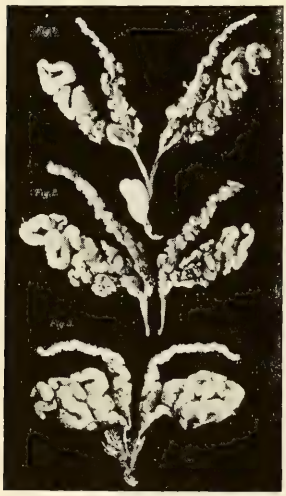

Fig. 433.—Corrosion Specimens Showing Multiplicity of Cavities in Vesicles.

In a recent report of 254 cases of seminal vesiculotomy performed on account of chronic inflammation of the seminal vesicles Fuller states that 124 cases, or about 50 per cent., were associated with "absorption or toxic rheumatism," and that all of these cases were relieved in a most radical manner by the operation of vesiculotomy. In his last series of 89 cases "80 per cent. of the patients were well and free from all symptoms when passed from observation a month or six weeks after operation." One of his patients operated on three years before, after having been on crutches for seven years, is now in perfect physical condition.

Besides the article of Fuller one found in 1912 practically nothing in the literature as to the operative treatment of these cases.

The operation performed by Fuller is so well known that I need not refer to it here. This procedure, which requires such extensive incisions on each side of the rectum and across the perineum and is seemingly so formidable, is shown by Fuller to be free from danger in that he has had no mortality in 254 cases.

An operation which I have devised is based on a desire to see the region of the prostate and seminal vesicles, and to be able to proceed thereon as indicated by the pathologic conditions found to be present.

The prostate is exposed as in perineal prostatectomy, the only difference being that instead of a sound in the urethra a long special prostatic tractor, which can be passed through the urethral meatus, is employed, as described in the radical operation for tuberculosis of the prostate and vesicles.

Before opening the fascia of Denonvillier a careful survey of the prostate and seminal vesicles and their relation to each other can be made. If it is desired that both lateral lobes of the prostate should be drained or excised the **Y**-shaped incision through the prostatic capsule and the fascia of Denonvillier described in the operation for tuberculosis should be made, as it gives an excellent exposure of the prostate and vesicles. If the case is one of very serious arthritis, endocarditis, or chronic sepsis, excise a large portion of one or both lateral lobes and remove completely one or both seminal vesicles, but do not excise the vasa deferentia unless they are found to be filled with pus. Even in

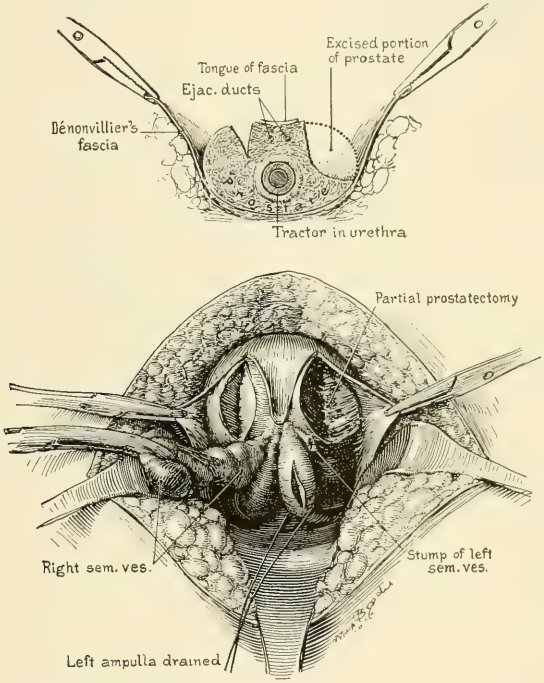

FIG. 434.—VARIATION: LEFT VESICLE AND LOBE OF PROSTATE EXCISED AND VAS DRAINED. RIGHT VESICLE BEING FREED. NOTE LINE OF INCISIONS IN PROSTATE (ABOVE).

such cases a free incision will usually be all that is necessary. Experience has shown that such removal of the seminal vesicles and lateral lobes of the prostate does not necessarily destroy sexual powers. Great care should be taken to have excellent hemostasis, the deep adhesions being clamped and then divided and ligated. The depths of the wound should be packed with wicks of gauze and small perforated drainage-tubes carried down to the bases where prolonged drainage of suppurative vasa or vesicles is desired. It is well to fasten the tubes with catgut and leave them in place for ten days or two weeks so as to insure drainage of the affected area for a prolonged period. The results are often startling in the rapidity with which inflammatory condition of the

joints and chronic rheumatism begin to disappear almost immediately after operation. I have seen cases absolutely bedridden, with a dozen or more fixed, red, swollen painful joints clear up, get out of bed, and return to work in a few months. The beautiful results obtained by drainage of the seminal vesicles have been brought forth by additional articles by Fuller and Squier, who have modified my technic by using traction sutures in the substance of the prostate instead of the long urethral tractor. Cunningham has also modified the operation by using a toothed retractor to draw down the base of prostate and seminal vesicles. Both of these modifications interfere with the continuity of the dissection of the seminal vesicles and lateral lobes of the prostate, and as the urethral tractor has been found of the greatest service not only in drawing down the vesicles and prostate but also in giving valuable assistance in determining the proximity of the urethra, ejaculatory ducts, and bladder in the careful dissection which is neces-

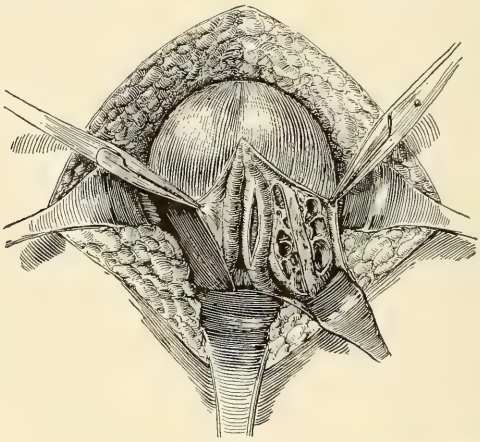

Fig. 435.—Variation: Showing Drainage of Vas and Vesicle for Chronic Inflammation. Posterior Wall of Vesicle Excised.

sary to avoid these structures during the excision of the suppurative lateral lobes and the adherent seminal vesicles, as shown in Figs. 434, 435. The facility with which this region can be attached and radical excision of diseased areas carried out without opening into the urinary tract or the production of urinary fistulæ has done away with the most serious objections to operations upon the seminal vesicles and prostate, not only in tuberculosis but also chronic inflammatory conditions.

Congenital Valves of the Prostatic Urethra.—An obstruction, more or less complete, due to the presence of abnormal valves of folds in the posterior urethra, has occasionally been described in the literature. The condition has always been regarded as one of great rarity. The great majority of the cases have been recognized only at autopsy, the diagnosis made during life having had no relation to the lower urinary tract. On reviewing the records of the Johns Hopkins Hospital for the past six years 12 cases not previously reported have been found, in

which the diagnosis has been confirmed by the instrumental methods, operation, or autopsy.

The earliest mention of the condition found in the literature is in the work of Langenbeck on Lithotomy, published in 1802. Thirty years elapsed before the subject was again referred to by Velpeau (1832), who described several anatomic specimens in which there were present in the posterior urethra valve-like folds which he felt might be of clinical importance. Tolmatchew in 1870 was the first to give a comprehensive discussion of the subject and recognized the condition as a pathologic entity.

During the past decade the development of the *x*-ray and renal function tests have made possible accurate diagnosis before operation.

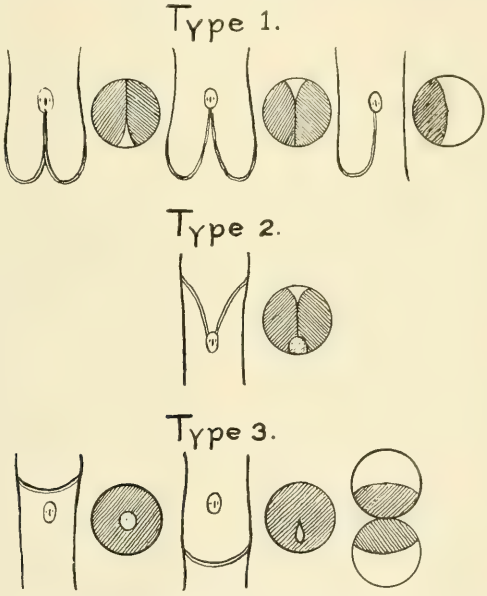

FIG. 436.—DIAGRAMMATIC SKETCH SHOWING VARIATIONS OF THE THREE TYPES OF CONGENITAL OBSTRUCTION OF THE POSTERIOR URETHRA.

In one of our cases the *x*-ray was used to confirm the diagnosis and to locate more accurately the point of obstruction. I successfully operated upon the case in September, 1913, the first operative procedure, we believe, to be carried out for the correction of congenital valve formation of the posterior urethra. It should be noted, however, that Bazy in 1903 diagnosed clinically and operated upon a case of valvular obstruction of the anterior urethra. Another patient came to the hospital for the cure of a second degree hypospadias. The alarmingly low renal function as determined by phenolsulphonephthalein suggested a further investigation which resulted in the diagnosis of congenital obstruction of the posterior urethra which was confirmed later at operation.

A study of our 12 cases and the 2 in the literature proves quite definitely that three general types of valve formations exist.

In the most common type there is a ridge lying on the floor of the urethra, continuous with the verumontanum, which takes an anterior course and divides into two fork-like processes in the region of the bulbomembranous junction. These processes are continued as thin membranous sheets, directed upward and forward, which may be attached to the urethra throughout its entire circumference.

In the second general type, of which we have one example, there occurs a more or less cylindric ridge similar to that found in the preced-

FIG. 437.—ILLUSTRATION SHOWING VALVES OF TYPE 1, SHOWING DILATATION OF POSTERIOR URETHRA, HYPERTROPHIED BLADDER, AND HYDRO-URETERS.
Insert giving detail of valve formation. Lindeman, F. P., Inaug. Dis., Jena, 1904. (See Case 9.)

ing type with the exception that it passes from the upper aspect of the verumontanum toward the internal sphincter. There it divides into two fork-like processes which are continued as membranous sheets and are attached to the urethra just outside the internal sphincter in a manner similar to that described in the foregoing type.

There is a third type which has been found at different levels of the posterior urethra and which apparently bears no such relation to the

verumontanum as the types just considered. This was first mentioned by Jarjavay in 1856, who described it as an iris valve because of the similarity in shape to the iris of the eye. This obstruction was at-

FIG. 438.—PLATE OF SPECIMEN SHOWING THE REMAINS OF CONGENITAL OBSTRUCTION (TYPE 2).
Note the dilated bladder, the marked hydro-ureter, and the bilateral hydronephrosis. The patient had been operated upon one year previously and the valves ruptured instrumentally. Insert shows dilatation of the sinus pocularis.

tached to the entire circumference of the urethra, there being a small opening in the center. Incomplete varieties of this type have been described, the most common being a more or less crescentic or semicircular fold crossing the urethra and being attached either to the roof or floor.

An interesting feature of these types of urethral obstruction concerns the arrangement of the folds which frequently offer little or no impediment to the passage of fluid or instruments from without inward, but which reduces greatly the caliber of the urethra during urination. The concave surfaces of the valves are always directed toward the bladder and are ballooned out by the ordinary stream. It should be noted in this connection, however, that except in those cases where only slight obstruction exists that the valves are continually ballooned out, at least when the patient is in an erect posture. In practically all cases in which the obstruction to urination is at all marked, the urethra behind the obstruction is always more or less filled with urine.

The changes in the bladder and upper urinary tract differ only in degree from those resulting from any urethral stenosis. The marked obstruction, together with its long duration, in many cases brings about extreme grades of hydro-ureter and hydronephrosis.

A review of the literature of congenital obstruction of the posterior urethra discloses but one case in which a confirmed diagnosis was made during life. So far as we are aware with this exception all of the reported cases have been discovered postmortem. This fact is quite surprising in view of the comparative frequency of the condition, the invariable history of obstructive symptoms since birth, and the ease of diagnosis by the application of modern methods. It seems advisable, therefore, to consider the following points in diagnosis.

A careful clinical history is the first indispensable step to correct diagnosis. The symptoms which are more or less characteristic of those resulting from obstruction to the outflow of urine will be somewhat modified by the degree of that obstruction and the age of the patient. In infants and very young children with severe grades of obstruction incontinence of urine is a very common symptom, the incontinence being naturally the paradoxic variety. Less severe grades of obstructive hesitancy, the passage of a small, weak stream, diurnal frequency of urination, and nocturnal enuresis are commonly met with. Indeed, the presence of any symptoms suggesting urinary obstruction in a male child or young adult, particularly when the urine is uninfected, should immediately call attention to the possibility of some congenital urethral defect.

In the more marked types of obstruction, particularly in those having incontinence, the bladder can frequently be felt as a firm conical or pear-shaped tumor extending as high as the umbilicus. In this type of case it is frequently possible to palpate the ureter as a large doughy mass extending between the bladder and the costal margin, in which region a hydronephrosis is sometimes palpable.

The use of instruments for viewing the urethra is naturally quite limited because the majority of cases when first seen are either infants or very young children. A small catheter can usually be passed and residual urine in varying amounts recovered. In many of these cases quite accurate information regarding the position of the valve and the degree of dilatation of the bladder, ureters, and kidneys is ob-

tainable by means of the *x*-ray. After the bladder has been completely emptied a solution of thorium or other suitable medium is introduced through the catheter by gravity and the *x*-ray picture taken. The accompanying illustration of this method shows not only the position of the valvular obstruction but also the extreme grade of hydro-ureter and hydronephrosis (Fig. 439).

Fig. 439.—Roentgenogram Made After 600 c.c. of Thorium Had Been Introduced into the Bladder by Gravity.

Note the dilated posterior urethra and vesical orifice, the irregular bladder outline, and the distended ureters and kidneys.

In the removal of congenital obstructions of the posterior urethra several methods are available. It may be possible in certain cases to remove the obstruction by forcibly passing a metal instrument through it, while in others the situation may be better handled by an urethrotome. In adult cases in which it is possible to pass the urethroscope it may be possible to remove the valve by scissors, rongeur, or fulguration. In 2 of our cases the punch instrument, which I devised for the removal of median prostatic bars, has completely corrected the obstruction.

The scope of the various urethral methods will naturally be quite

limited because of the fact that the majority of cases are first seen in infancy or early childhood. In view of this fact the removal of the obstruction through a suprapubic cystostomy will most frequently prove to be the method of choice. In 4 of our cases operated on by this method the valve was destroyed in one by electrocautery, in another by the finger, and in the third and fourth cases by a sound and rongeur respectively.

The functional results of operation in cases of congenital obstruction of the urethra are very satisfactory, but the prognosis in a given case will depend naturally upon the changes in the upper urinary tract subsequent to back pressure and infection. In young children in whom the obstruction is not extreme and the renal damage relatively slight the outlook is most encouraging. In our series extreme grades of renal destruction have been present in all of the adult cases, and operation has been followed by improvement both in renal function and in general health. Of my 12 cases, 8 were operated upon successfully. Of the 23 cases in the literature, all died but one. See full report.

Calculi of the Prostate.—This condition has been shown to be of increasing importance by several articles which have appeared during the past six years. The most important is that of Kretschmer.[3] This article is particularly valuable because it contains a very extensive bibliography.

Kretschmer presents 8 personal cases in detail, with interesting *x*-ray photographs which show the calculi in the region of the prostate; 165 cases were found in the literature, bringing the total recorded to 173. The symptomatology is valuable. The most important are pain, passage of calculi, and abscess formation. Nearly all patients complain of pain some time during the course of their illness. It may be localized in the region of the prostate or referred to the perineum, anus, penis or suprapubic area, and even down the thighs. The pain in the perineum may be aggravated by sitting. Occasionally calculi are passed per urethram.

A recent author has reported cases in which he has been able to force the calculi into the anterior urethra by prostatic massage. Abscess is rare. Dysuria was present in 16, difficult urination in 17, and dribbling in 5. Hematuria occurs occasionally. In 27 cases the patient used a catheter. Sexual symptoms do not occupy as prominent a position as urinary symptoms, yet in several instances they were the chief complaint. Rectal symptoms which occur are tenesmus and pain. Calculi were present in the bladder in 11 cases and in 2 cases in the kidney and ureter. Authorities agree that in most cases prostatic calculi formed in the substance of the prostate, but there is divergence of opinion as to the etiology (this has been discussed previously in Volume IV.).

Diagnosis.—Kretschmer asserts that the diagnosis can be made in every case by the *x*-ray. Forscell has described two types of shadows, one in which the calculi are very small and round, varying from pinhead to hemp seed in size, and arranged symmetrically in small groups

near the median line. Calculi may be found in other portions, sometimes on both sides of the midline or irregularly placed in the region of the prostate. On rectal examination suspicion of calculus may be aroused by changes in the prostate, crepitation, palpation of the stone, or compressing the calculus into the urethra. Kretschmer gives the following clinical indications:

Crepitation, when elicited, has often been mentioned as being pathognomonic of prostatic calculi.

In order to demonstrate stone by direct palpation the calculus must have attained fairly large size. In cases in which the stones are fairly large the parenchyma of the gland surrounding the calculus has often become more or less atrophic, so that the calculus may be easily felt.

Expressing the calculus from the prostate by prostatic massage may occur in cases in which the calculi are small. The presence of more calculi in the prostate should be verified by roentgenograms. Calculi have been expressed from the prostate in 6 cases.

The rectal examination in many cases demonstrates an increased consistency of the prostate. At times the prostate may be described as being hard as stone. Increased consistency of the prostate occurring in early adult life should arouse one's suspicions of the possibility of the presence of calculi, whereas in older persons great induration may be significant of malignancy.

Treatment.—Small calculi producing no symptoms and accidentally discovered usually do not require removal. Those found associated with benign hypertrophy should be carefully evacuated after prostatectomy. Owing to the fact that they are usually found in the periphery of the prostate outside of the adenomatous mass, their removal is more certainly secured by the perineal route, which makes it possible to inspect and remove the calculi embedded in normal gland substance. Those that may not be found at operation have a better chance to escape through the perineal wound than through a suprapubic opening. In some cases, not associated with hypertrophy, the calculi should be removed on account of the symptoms produced. Kretschmer feels that the removal of calculi by massage or the endoscope have a very limited field of use, and says that the radical removal of calculi can best be performed by perineal prostatotomy. This operation was described in Volume IV.

Prostatic Bar Obstruction, or Contracture of the Prostatic Orifice.—In Volume VI reference was made to progress in the treatment of median bar obstruction or contractures of the prostatic orifice, with a review of the literature and a presentation of my punch operation.[1, 2] Since then interest has been stimulated in the subject, and extensive articles and discussions have been published.[4] These have demonstrated that this form of prostatic disease is far more common than generally supposed, thus confirming our earlier observations.

In his two articles Randall has done much to systematize the pathology, and I will quote from his second paper[8] in which he has carefully studied at autopsy 300 bladders in men aged between ten and eighty

years of age. In them he discovered 54 cases of "obstruction at posterior vesical lip" or "median bar formation." Of these 54 bars, 18, or 6 per cent., of the prostates examined were marked, and in 36, or 12 per cent., small.

Randall describes the mechanical condition found under four types, viz.: I. An abrupt bar or dam rising from or stretched across the posterior lip of the vesical orifice, formed of firm, dense, sclerotic tissue, whose edge is sharp and narrow, and whose lateral terminations form an abrupt angle with the lateral walls of the vesical outlet. Microscopic: The study of sections of this type of fibrous bar have shown different degrees of an inflammatory sclerosis. In the depth can also be found similar changes going on in and around the gland acini.

There have been four specimens of this type classified as large bars. They occurred at the ages of fifty-eight, sixty, sixty-seven, and sixty-five years. All four had advanced chronic interstitial nephritis. The younger died in uremia. Two had markedly trabeculated bladders, in each case associated with the formation of diverticula, and the fourth with bilateral dilated ureters and hydronephrosis.

There were 21 cases classified as small bars of this type, varying in age from twenty-six to seventy-four years.

II. A type of fibrous bar whose projection has a tendency upward or vesicalward, and seems to encroach upon, or draw upon, the vesical trigone more than upon the urethral surface. It causes a shortening of the vesical trigone by a transverse creasing. This subvariety of fibrous bar is not essentially different from the first as to its microscopic structure; it is not associated with the urethral shortening so characteristic of Type No. 1. There have been five specimens of bars of this type; three classified as large, occurring at the ages of fifty-five, sixty-five, and seventy-nine years. Those classified as small occurred at the ages of forty-three and forty-four years.

III. A glandular bar with the hypertrophic process confined to the gland acini of the posterior prostatic commissure, inside the prostatic capsule and under the sphincter muscle. It raises the posterior vesical lip into a thick, broad, obstructing bar, unassociated with visible hypertrophic changes in the lateral lobes. On section there is found a layer from 6 to 8 mm. in thickness of uniform fibrous and muscular tissue, more than occurs in a perfectly normal vesical lip, but not comparable with the true fibrous bars. Below this is seen distinctly a circumscribed area of glandular tissue, in some cases 2 cm. in diameter. In all specimens prostatic hypertrophy was found here associated with inflammatory sclerosis.

There were 10 cases in all placed in this classification. There were 4 cases classified as large bars, occurring at the ages of forty-six, fifty, fifty-two, and fifty-six years. In 2 there was a slight lateral lobe hypertrophy.

There were 6 cases classified as small bars of this type, occurring at the ages of twenty-six, forty, fifty-three, fifty, fifty-five, and sixty-three years.

IV. The type of glandular obstruction caused by the isolated hypertrophy of Albarran's subcervical glands in the shape of a rounded lobe with lateral cleftings, varying from a small lobular mass or nodule lying in the internal sphincter's grasp, up to that of a large intravesical lobe.

Microscopic: One sees a proliferation of gland acini, a pronounced glandular hyperplasia, which lies directly under the mucous membrane.

Fourteen specimens have fallen into this group, 7 were large and definitely obstructive. The ages varied from thirty-six to seventy-three.

Summary of Randall's Findings.—(1) There have been examined 300 autopsy specimens in the adult male. They have shown median obstruction to the vesical outlet in 18 per cent., or 54 cases. These have been shown to be either (*a*) fibrous, 10 per cent., or (*b*) glandular, 8 per cent.

(2) The fibrous type of bar has been subdivided into two varieties according to whether the process has encroached upon, or drawn up (*a*) the urethral or (*b*) the vesical surface in its development. In the former group occur 83.3 per cent., in the latter 16.6 per cent. They have been shown to be inflammatory in character and to be but a part of a generalized chronic interstitial prostatitis.

(3) The glandular type has also been subdivided into two varieties according to whether the hypertrophic process is confiened to (*c*) the posterior prostatic commissure, inside the prostatic capsule and under the sphincter muscle, in which case a thick, broad bar is formed; or (*d*) the subcervical glands of Albarran, occurring just under the mucous membrane, and within the sphincteric ring, and forming what Zuckerkandl has so aptly called "prostatic hypertrophy in miniature," *i. e.*, a small obstructing lobule.

(4) The vast majority of even the glandular types of bars also have been associated microscopically with inflammatory connective-tissue proliferation and tending to fibrosis.

(5) Age has not been a differentiating point in any series or type. The youngest case classified as large, of the fibrous type, was fifty-five years of age and the oldest seventy-nine years. In the glandular types the youngest was forty-six years old and the oldest seventy-three years, though there were 3 under fifty years.

(6) Microscopic study has demonstrated a concomitant infectious process in all cases of true median bar information, and has pointed to a chronic prostatitis as the actual underlying cause.

Tenney[5] has presented an interesting study of "obstruction without hypertrophy of the prostate" in 64 cases which he collected from the literature and from personally contributed cases. One per cent. of 816 prostatic operations previously collected and discussed by Tenney were operated before fifty years of age, while 20 per cent. of the 64 cases reported to Tenney were operated before that age, and 30 per cent. were operated before sixty, as compared with 16 per cent. of the general prostatic operations. Approximately one-third of the cases reported to me gave a history of previous gonorrhea.

Of the 64 cases reported by Tenney, 46 were operated on through the

bladder and 13 through the perineum. There were 4 deaths, 3 of which followed perineal section, but some of these cases were attempts to remove hard fibrous prostates, and this operation is often long and difficult. They cannot fairly be compared with a list of cases whose lesions were confined to the region of the internal sphincter. The results of the operative treatment were satisfactory in 47, unsatisfactory in 11, death in 4, [mortality rate 6.3 per cent.], not given in 2 cases. Unsatisfactory results followed the perineal operation seven times, suprapubic operation three times, and Bottini cautery once.

Of Tenney's patients, one man still has rather frequent and sometimes painful urination, though not enough to drive him to an operation. Four others, one a tabetic, had a perfect functional result, and a fifth, seventy-two years old, died suddenly after his return home with a healed and comfortable bladder.

Tenney concludes: "Cases with extensive fibrous changes in the gland are benefited by operation, but the duration of the improvement depends on the persistence of patient and surgeon in the after-treatment. Without this they may easily relapse into a condition as serious or worse than that which first sent them to the surgeon. They are unfinished pieces of surgery."

In conjunction with Cecil I have presented an analytic study of 156 "punch operations"[9] and have brought our statistics up to date for this volume, and herewith present a similar analysis of 181 cases of obstruction at the prostate orifice in which the "punch" was used to remove the obstruction:

Age of patients.	Number.
Under twenty years	1
Twenty to twenty-nine years	5
Thirty to thirty-nine years	14
Forty to forty-nine years	44
Fifty to fifty-nine years	49
Sixty to sixty-nine years	42
Seventy to seventy-nine years	21
Over eighty years	3

Urinary Symptoms.—Frequency of urination 125, hesitancy 63, urgency 26, small stream 48, weak force 41, sudden stoppage 15, incomplete urination 16, retention: complete 3, occasional complete 13, incontinence 2.

Pains.—Neck of bladder 36, perineum 26, end of penis 25, throughout urethra 23, back 12.

Sexual Symptoms.—Desire: lost 12, impaired 23. Erections: absent 6, imperfect 11, painful 1. Ejaculations: precocious 8, absent 7, painful 5.

Obstruction.—Complete retention 5, large residual (over 200) 21, moderate residual (50 to 200) 49, small residual 84, no residual 18, not stated 3.

Cystoscopic Findings.—Median bar 155, lateral enlargement 42, anterior bar 22, polyp at vesical orifice 6, diverticulum 25, trabeculation 44, stone 15, hypertrophied trigone (mixed) 3.

The technic of the operation and the after-treatment at present differ considerably from that employed when the operation was first described. At first the urethra was anesthetized with 4 per cent. novocain or 2 per cent. cocain, the instrument was introduced with the cutting tube in place until the beak had just entered the bladder. The inner tube was then withdrawn, the urethroscopic lamp attached, and observation made to see just what portion of the urethra the instrument occupied. The verumontanum usually occupied the field. The instrument was then introduced further until the median bar filled the fenestra. The lamp was then disconnected and the knife quickly pushed home, excising all of the median bar which occupied the fenestra

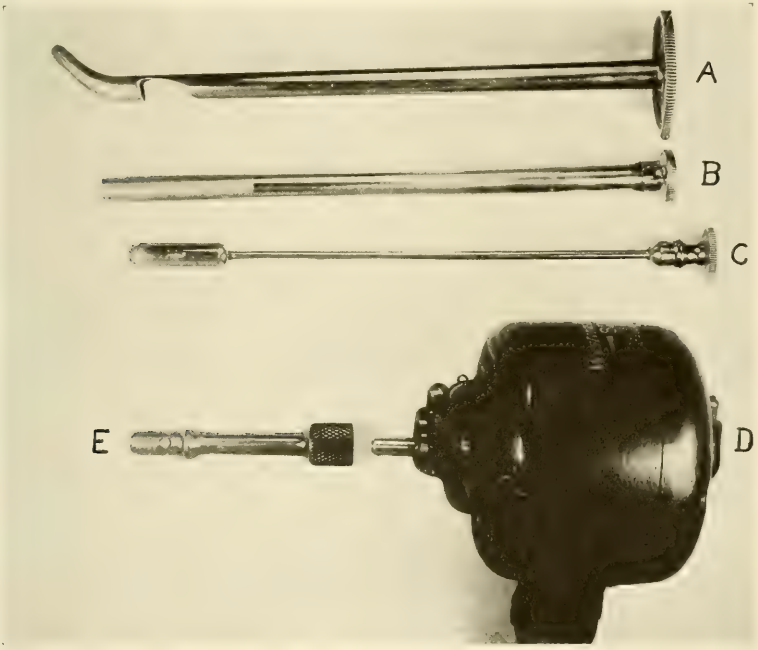

FIG. 440.—*A*, YOUNG'S PROSTATIC "PUNCH" INSTRUMENT; *B*, INNER CUTTING TUBE; *C*, OBTURATOR; *D*, ELECTRIC MOTOR TO ROTATE INNER CUTTING TUBE; *E*, CONNECTING ROD.

of the instrument. Usually three cuts were made, posterior, right, and left lateral. The bladder was then irrigated and the instrument withdrawn. Immediately a two-way gum coudé catheter was introduced and continuous irrigation kept up for twenty-four to forty-eight hours, when the catheter was removed. (For full description see Vol. VI.)

Since that time important improvements have been made in the instrument, the technic of the operation, and the after-treatment. A new non-rusting steel of high tensile strength has been found, and the instrument largely constructed of this material, thus furnishing much better execution in excision of the portion of the prostate which is entrapped in the fenestra. Second, it has been found perfectly feasible to carry out the operation accurately without the use of the urethroscopic

attachment. Third, the instrument is far more efficient if the inner tube is rapidly rotated when being pushed in. Accordingly, a small motor is attached to the cutting inner tube or knife by a brass connecting

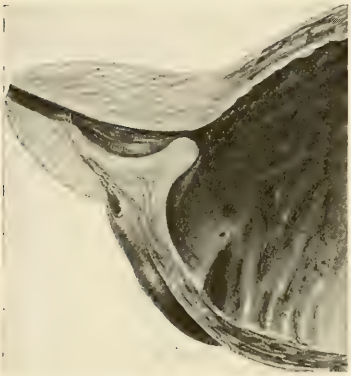

FIG. 441.—SAGITTAL SECTION SHOWING MEDIAN BAR BEFORE INSERTION OF INSTRUMENT, THE BLADDER HAVING BEEN MODERATELY DISTENDED WITH WATER.

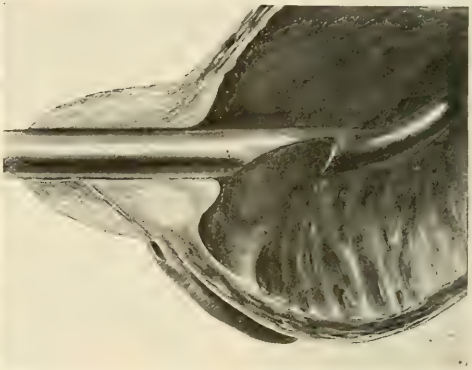

FIG. 442.—THE PUNCH INSTRUMENT HAS BEEN INSERTED AND THE INNER TUBE WITHDRAWN FAR ENOUGH TO PERMIT THE FLUID TO BEGIN TO FLOW OUT.

piece. A small slot is cut in the side of this inner cutting tube into which fits a pin on the brass connection rod. There is a hole in the end of the connecting rod into which fits the shaft of the motor (Fig. 440).

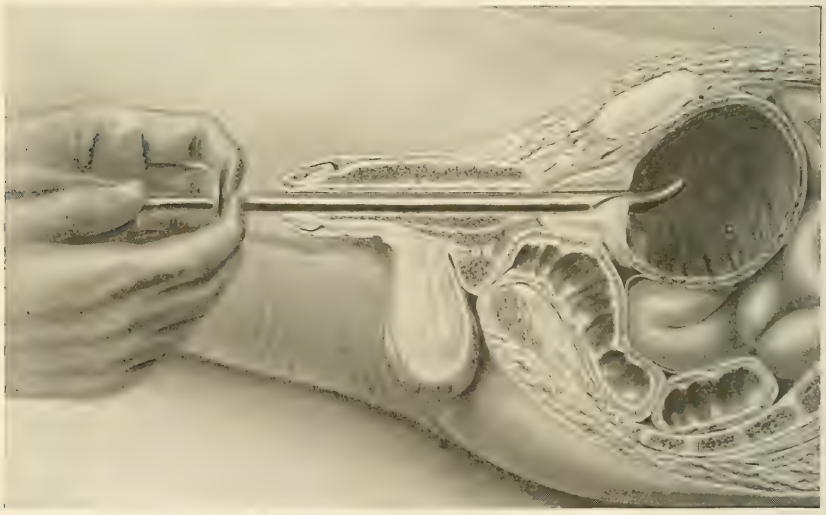

FIG. 443.—THE OUTER TUBE HAS BEEN WITHDRAWN FAR ENOUGH TO ENTRAP THE MEDIAN BAR IN THE FENESTRA, AS INDICATED BY A CHECKING IN THE FLOW OF FLUID.
The hands of the operator are shown ready to push the inner tube home.

The operation as now carried out is graphically shown in the accompanying illustrations (Figs. 441–447). First the urethra is anesthetized with 4 per cent. novocain or procain. A catheter is then passed and the urine evacuated. Then the bladder is filled with as much sterile water

as the patient can hold without discomfort and the catheter withdrawn. The punch instrument is then passed well into the bladder with the inner tube in such a position as to completely fill the fenestra. The inner tube is then withdrawn a short distance, allowing the fluid to escape, and thus showing that the fenestra is in the bladder (Fig. 442).

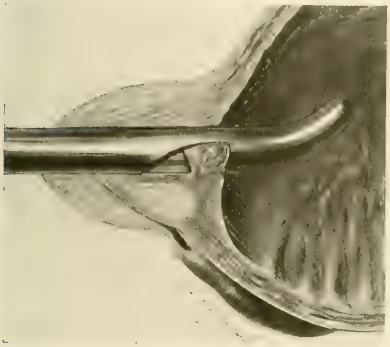

Fig. 444.—Shows the Inner Tube Beginning to Cut Through the Median Bar.

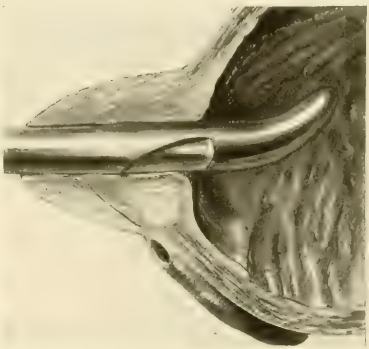

Fig. 445.—The Inner Cutting Tube Has Been Pushed Home, Inclosing Within Its Lumen the Incised Portion of Median Bar.

The instrument is then rotated so that the fenestra is directed properly for the first cut, and the instrument slowly drawn outward until suddenly arrested and the escape of fluid stopped simultaneously, showing the fenestra has entrapped that portion of the margin selected for excision (Fig. 443). If the instrument is directed posteriorly it should now

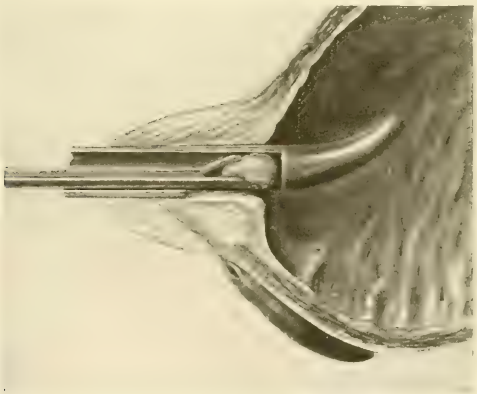

Fig. 446.—Sectional View of Outer Tube, Showing Removal of Excised Tissue with Alligator Forceps, the Cutting Tube Having Been Withdrawn After the First Cut.

be rotated 90 degrees and traction made, to be sure the tissue engaged is not the trigone. If no fluid now escapes it is evident that the bar has been caught, and the instrument is turned back to its original position and the knife pushed in until it just touches the tissue to be excised. This maneuver is very important, for if the trigone has been caught, by turning the instrument 90 degrees it will be released and the fluid will

escape. The brass connecting rod is next attached to the knife and held in position by the operator. The assistant now starts the motor, places its shaft in the opening of the connecting rod, and slowly pushes the cutting inner tube home (Figs. 444, 445), excising all the tissue which project into the instrument through the fenestra. The motor is at onced stopped and disconnected from the punch, and the plug of tissue made by the cut is removed by means of a long pair of urethroscopic forceps (Fig. 446). The amount of tissue removed by this method is distinctly greater than the old procedure, and I feel sure the results will be even better than those previously reported. In the majority of the cases three cuts are sufficient, but in some cases of anterior bar as many as six have been made, the entire circumference of the prostatic orifice being attacked. On completion of the operation the bladder is irrigated through the punch, which is then removed, the obturator having been inserted, and a large gum coudé catheter introduced (Fig. 447) and strapped in the urethra with adhesive. The two-way

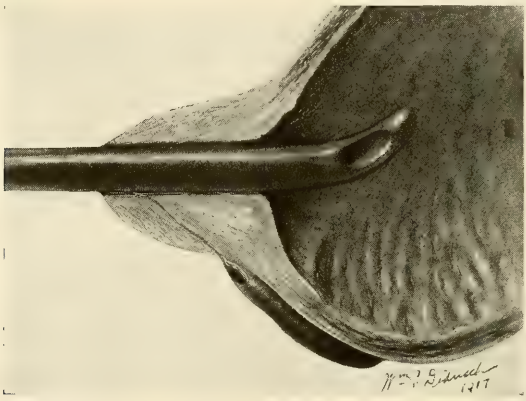

Fig. 447.—Coudé Catheter Inserted Immediately After Operation and Allowed to Remain Thirty-six to Forty-eight Hours.

catheter is no longer used because a single, fairly large (26 to 28 Fr.) coudé gum catheter has been found more satisfactory, as clots are more easily removed by suction with a large syringe. The continuous irrigation has been found to lead to more hemorrhage. The post-operative treatment consists of maintaining continuous drainage and the prevention of hemorrhage or arrest of any that may be present. Immediately the patient returns to the ward he should be given $\frac{1}{4}$ grain of morphin. During the first twenty-four hours he should be kept perfectly quiet, if necessary by the use of repeated doses of morphin, $\frac{1}{2}$ grain about every four hours, particularly if there is any tendency to bleeding. In the after-treatment it is extremely important that a good piston syringe is at hand for prompt evacuation of all clots. Not infrequently it is necessary several times during the first twenty-four hours following the operation, but with great care no difficulty should be experienced. It is imperative, however, that continuous drainage be maintained, as a full bladder leads to great pain and further hemorrhage.

Irrigation is only used to aid in the removal of clots. The catheter is allowed to remain forty-eight hours unless the urine is still bloody, in which case it is left for about twelve hours after the urine is perfectly clear. No postoperative urethal dilatations are needed. They do not develop stricture and do not recur.

The important points are to maintain continuous drainage, force water, and keep the patient quiet and comfortable, and hemorrhage will usually not be a troublesome factor.

Complications: Hemorrhage has been an occasional complication Nearly all patients have sufficient bleeding to plug the catheter several times during the first twenty-four hours. A few have bled enough to cause some alarm (causing us to give saline transfusions, etc.), while 3 have had suprapubic operations to stop hemorrhage that otherwise could not be controlled. One of these cases had a prostatic cyst removed with rongeur cystoscope followed by punch operation; one had a very greatly contracted trabeculated bladder; the other was an uncomplicated punch operation. This is the only case out of 178 bar cases to require syprapubic drainage.

There were 2 cases operated upon who had what we think were coincidences rather than complications, but I think it is wise to mention them in this connection. One was a case who had had perineal prostatectomy five and a half years previous to present admission. On examination it was evident he had carcinoma of the prostate, and the punch operation was done for relief of painful and difficult catheterization. He had a definite cocain poisoning which quickly subsided. He, however, became very toxic on the second day and died. Autopsy showed a very marked pyelonephritis, which was thought to have surely existed before operation, and cancer of the prostate. There have been no deaths in simple bar cases. The other was a patient who developed psoas abscess eighteen days after operation. This was not definite at first, but thirty-four days after operation incision and drainage of a right psoas abscess was done. This, however, did not completely relieve pain in the back. Subsequently he has had two other operations for psoas abscess, the last one being about a year after his punch operation. At these operations a tuberculous necrosis of the spine was discovered. Since that time the patient has had complete recovery and reports himself cured.

The results of the operation based on examination of those patients who returned for observation and on questionnaires sent to those who did not return is as follows:

Condition.	Cases.
Cured	91
Improved—90 per cent.	31
Improved—75 per cent.	17
Improved—50 per cent.	12
Improved—25 per cent.	5
Not improved	16
Made worse	2
Not heard from	3
Died (cancer, pyelonephritis)	1

The patients reporting themselves "90 per cent. improved" had no symptoms of obstruction, but still had slight pain, usually in the back or deep urethra. The same is true to a large extent of those reporting themselves 75 and 50 per cent improved.

Of the 5 patients who reported themselves 25 per cent improved, 2 required subsequent prostatectomy, which showed definite hypertrophy present. The other 3 patients had interstitial cystitis, one of whom had a large diverticulum.

Of the cases not improved, 5 had interstitial cystitis; 3 later underwent perineal prostatectomy; one was a case of pain in the posterior urethra with median bar; one had previous perineal prostatectomy, punch, and later suprapubic cystotomy.

A study of the histories of the cases "not improved" shows that in some cases a definite hypertrophy of the lateral lobes of the prostate was present, in others marked cystitis and contracture of the bladder, which has not been relieved and is the present cause of the symptoms complained of. In others vague pains were present associated with slight bars, and it was hoped to cure them by the punch, but the pains still persist. In 2 cases the bladder was greatly distended and atonic. In both of these cases the atony persists. The operation has been used by us in some cases not suited to the procedure, in the vain hope of benefiting a troublesome case. Our series of cases have demonstrated conclusively that the punch operation is based on sound operative and mechanical principles, and is perfectly suited for prostatic orifice, median posterior or anterior bars or valves, circular contractures or strictures of the prostatic orifice, small median lobes not associated with more than slight hypertrophy.

It is an operation requiring most careful preliminary study of the case and a most careful attention to technical detail at operation and afterward. It is, therefore, not an operation for wide-spread popularity and general adoption, but in places where proper provision has been made for delicate and difficult urologic work and resident doctors and orderlies are trained and interested, most beautiful, nay, brilliant, results can be obtained by the simple procedure.

Prostatic Hypertrophy.—During the past seven years the literature of prostatic hypertrophy has been very extensive, but among the hundreds of articles that have appeared there is little that is very new concerning the diagnosis and treatment, but attention has been turned rather to details of pathology and technic and a study of ultimate results. The importance and relative frequency of cancer, which was stressed in both Volumes IV and VI, has gained ground in the profession, and we find a general unanimity that cancer occurs in from 14 to 20 per cent of the cases of obstructive prostates. We have selected from the literature several important papers for comment.

Relation Between the Symptomatology and Character of the Prostate.—In a very careful clinical and laboratory study Legueu[6] presents many interesting figures on this subject. The material consisted of

specimens of 300 cases upon which he had operated. The weight of the adenomas was as follows:

Weight, grams.	No.	Per cent.	Retention, chronic, per cent.	Retention, incomplete, per cent.	Retention, acute, per cent.	Dysuria, per cent.
Over 100	31	10	6	45	15	33
Over 80	9	3	0	11	55	33
Over 45	22	7	36	50	0	13
31 to 35	32	10	15	31	46	6
Below 30	141	47	22	34	20	21
Below 15	78	26	25	37	15	21

Legueu remarks that there is no relation between the size of the prostate and the importance of the symptoms and retention is not proportional to the volume of the adenoma. He mentions that he has seen numerous cases of very large prostates with no retention of urine.

Studying the 300 cases from the standpoint of comparison of the lobes he found as follows:

MEDIAN LOBE

Size.	Cases.	Per cent.	Complete retention, chronic.	
			No.	Per cent.
Enormous	10	3	3	6
Moderate	28	9	6	15
Insignificant	40	13	8	17
Not present	222	74	30	63
Total	300		47	

Size.	Retention, incomplete,		Retention, acute.		Dysuria.	
	No.	Per cent.	No.	Per cent.	No.	Per cent.
Enormous	3	3.5	1	1.8	1	1.4
Moderate	10	11	6	11	1	8
Insignificant	15	17	..	..	6	...
Not present	58	65	47	88	61	
Total	86		54		69	

Legueu draws the conclusion from these statistics that the median lobe does not play an important part in retention of urine, and mentions a case in which the middle lobe weighed 100 grams and there was no retention of urine. He considers the condition of the vesical neck the most important. "Sometimes the neck is wide open, allowing two or three fingers to penetrate without difficulty (163 cases—54 per cent.). In other cases it is closed, preserving the aspect of the normal neck, and at other times the relative suppleness, but more often rigid and almost impossible to dilate and break through (79 cases—26 per cent.)."

Complete chronic retention was found in 35 per cent. of the cases with narrowed orifice, and on only 11 per cent. of those of the large orifice. Concerning "les prostatiques sans prostate" Legueu has this to say: "Heretofore we have thus designated those prostatic cases which in spite of presenting the functional symptoms of hypertrophy and notably retention, do not show the presence of any edenoma on examination. In the majority of patients which have been thus labeled

one finds at operation small adenomatious nodules which are easily recognizable, but these patients are not all of those diagnosed prostatics without prostate."

Among the 300 cases operated upon there are 78 in which the tissue removed weighed less than 15 grams. These may be divided into three groups: First, in which the tissue removed on microscopic examination shows a small adenoma. He mentions a case in which the orifice was normal, the urethra large without any obstruction, and apparently no pressure either right or left, but on plunging his finger into the prostatic tissue he removed two adenomas of the total weight of 9 grams. Second, cases in which one cannot recognize any adenoma by the naked eye, and finds it only on microscopic examination in a stroma of muscular hypertrophy. Third, in which no adenoma is found even on microscopic examination. The tissue removed is small and the change present is more muscular and fibrous than glandular.

Legueu considered that some of these cases demonstrated the presence of other than mechanical influences, but he concludes that the prostatic disease in all its forms is a disease of the vesical neck characterized by hypertrophy of all the elements—mucous, glandular, muscular, and fibrous—which constitute it.

It is very evident that very many of the cases in which Legueu did a suprapubic prostatectomy could have been cured by a punch operation under local anesthesia.

Treatment Preliminary to Prostatectomy in Unfavorable Cases.—Twenty years ago the mortality for prostatectomy was estimated at 20 per cent. Today in some clinics it is less than 3 per cent. What has brought about this marvelous change? More accurate diagnosis and better operative technic have, of course, done much to reduce the mortality—the substitution of accirate operations, under visual control, for destructive procedures done in the dark, being one of the principal factors.

But much of the early mortality was due to complications, resulting from conditions existing before operation which were overlooked or neglected. In 1898 I operated on a patient who came to the hospital in severe uremia. A catheter could not be passed, suprapubic drainage was all that could be done, and the drainage afforded worked a seeming miracle. In a few days consciousness returned, and within a few weeks prostatectomy was carried out without difficulty and with success Since then I have had a full realization of the wonderful benefits of preoperative drainage in all prostatic cases in which the kidneys have been impaired by long-standing back pressure.

At first we employed suprapubic drainage in all such cases (now called the "two-stage method," as if it were a new idea); but before long we came to realize that the same result could be accomplished by inlying catheterization. One of the most striking of these early patients (in 1889) was a man, aged seventy-six, who was comatose and very septic; catheter drainage and infusion were not sufficient to abate his uremia, so we employed blood-letting and simultaneous saline transfusion in the

opposite arm, together with salt solution by rectum. After carrying out these strenuous methods for several days the infection and uremia both disappeared, and in six weeks a prostatic operation was successfully carried out.

Employing the knowledge gained from similar experience, we were the first to advocate systematic preparatory treatment in prostatic work where serious involvement of the bladder, kidneys, heart, etc., was present, and as a result in 1908 were able to report 128 consecutive perineal prostatectomies without a death, 2 of the patients being over eighty years and 43 over seventy years of age.

In the early years of this work the physical condition of the patient, presence of much residual urine, and evident symptoms and signs of poor kidneys were the principal indexes which guided us in our decision as to when to delay operation and to resort to preparatory treatment. The phlorizin test and freezing-point were experimented with without much help. When the value of phenolsulphonephthalein was first shown in the urologic department in 1910* it was quickly applied to prostatic cases, and found to give the index of renal impairment which we had previously been able only to surmise or guess at.

As time went on the desirability and value of additional tests for the blood, heart, etc., have been demonstrated, so that now a complex but remarkably helpful series of routine tests are employed in almost all cases.

Too great care cannot be exercised in the study of these cases preliminary to operation. Abnormalities of one kind or another are the rule rather than the exception, and the surgeon who disregards or overlooks these danger signals fails to reduce his mortality to the minimum. A careful physical examination, which should include a blood-pressure reading, is, of course, essential in every surgical case. Of special importance in prostatic hypertrophy is an examination of the urine, the determination of the residual urine, and a study of the renal function.

If on examination no organic disease is demonstrable, the blood-pressure normal, the urine free from pathologic elements, and the renal functions satisfactory, an early operation can be carried out, with the realization that, from a clinical standpoint, the patient is an excellent surgical risk.

There is one important exception, however, which should be emphasized. The presence of a large residual urine, even though there be no infection and the renal function fair, furnishes a considerable risk if operation be performed without preparatory treatment. These are patients often with atonic bladders, dilated ureters, and varying grades of hydronephrosis, and without preliminary catheterization the danger of acute uremia and ascending infection is greatly increased.

Unfortunately, an ideal physical condition is the exception, and the risks may be classified as follows:

I. *Cases with Renal Impairment.*—Of the factors complicating prostatic obstruction, impairment of renal function is perhaps the most

* See report of Rountree and Geraghty.

frequent. The condition may be either primary or secondary, or both may occur in combination. Of the former, chronic nephritis and chronic passive congestion from cardiac decompensation are the more frequent forms.

Advanced grades of renal derangement may result simply from the back pressure of residual urine, and may or may not be associated with infection. The uninfected case responds promptly as a rule when free drainage of the bladder is established, the renal function approaching normal in a short time, provided the condition is not complicated with nephritis. With the infected group, however, the improvement is variable, the rapidity of response to treatment depending entirely on the degree of renal destruction. The involvement in these cases ranges from a pyelitis to an extensive pyelonephritis or pyonephrosis, and the functional capacity from normal to a point approaching zero. The severer forms of this type of case offer an extremely grave prognosis if operation is attempted during the period of renal insufficiency. The danger, however, lies not alone with the kidney. In many of these cases a condition which may be termed "lowered vitality" is present. The patient is weak, undernourished, and lacking in resistance. A fatal termination after operative interference may result from renal failure; but this is frequently merely a part of the closing scene, the principal rôle being played by infection. Marked impairment in the functional capacity of the kidney may be due to cardiac insufficiency; in these cases the condition may be purely a circulatory one, the renal function returning to normal as cardiac compensation is established.

The determination of the operative risk from the standpoint of renal efficiency requires an accurate knowledge of the functional capacity of the kidneys, and in securing this information two methods are available:

(*a*) *Phensolsulphonephthalein.*—This is essentially a test of the excretory function by quantitative determination of various substances appearing in the urine in a given time after injection. Of these substances various dyes and other chemicals have been employed. Phenolsulphonephthalein has proved eminently satisfactory and the most practicable of all the tests.

While we have always pointed out that no mathematic valuations for the phenolsulphonephthalein reading, as to safe and unsafe cases, could be dogmatically promulgated, the great accuracy of the phenolsulphonephthalein test cannot be denied. This is because of the fact, now well established, that in cases in which the kidneys are markedly impaired an operation can be carried out without great risk of severe postoperative uremia if the kidneys have arrived at a condition of stability in their impairedness. When preoperative studies show that a patient has "a poor phenolsulphonephthalein test," he is always put on the "waiting list" and the usual catheter treatment and other preliminary measures inaugurated. Semiweekly phenolsulphonephthalein tests are then made and compared, and in most cases a steady improvement occurs from day to day; but when a stationary period is arrived

at, the question to be determined is: Is the condition now stable, so that sudden postoperative uremia is probably not to be feared; or if a chronic nephritis with irremediable impairment has been demonstrated, is it sufficiently bad to prohibit operation? In arriving at this decision the blood urea test is a great help; but aside from the laboratory aids, clinical judgment and experience are often of decisive value—though it is even more dangerous, and a reversion to ancient inaccurate methods, to determine one's action solely or even largely on clinical opinion.

If we can get a phenolsulphonephthalein test above 30 per cent. for the first hour and gradually rising in the semiweekly tests, we generally feel perfectly safe, no other dangerous complications being present. But if the patient has never been catheterized before, and especially if the residual urine is large, two important possibilities must be constantly feared, namely, sudden uremia (resulting from the removal of long-standing and well-compensated back pressure) and infection.

(*b*) *Blood Urea.*—In certain cases, particularly those with a low phenolsulphonephthalein output, as has been indicated, further information of the renal function may be obtained by determining the concentration of urea in the blood. The retention of urea and other nitrogenous bodies is generally an evidence of renal insufficiency, and the degree of retention, as a rule, is in inverse proportion to the phenolsulphonephthalein output. Notable exceptions to this inverse parallelism are seen, and a very low phenolsulphonephthalein reading is not incompatible with a normal blood urea.

A stable phenolsulphonephthalein test, however low, with a normal blood urea, does not necessarily contraindicate prostatectomy, and many of these cases prove fair operative risks from the renal standpoint. A low excretory function, however, with high urea retention is to be regarded as dangerous. A marked diminution in the phenolsulphonephthalein output with a proportionately high blood urea is twofold proof of renal insufficiency, and operation may be followed promptly by uremia.

The estimation of blood urea is at times the only method available for determining the degree of renal efficiency. The presence of large amounts of blood in the urine may render the phenolsulphonephthalein reading inaccurate, and in cases with urinary fistulas the collection of the entire urine for a given time may be impossible.

A small percentage of these patients fail to improve, so far as the renal function is concerned, after the usual preliminary measures are carried out. These are cases either of extensive renal destruction, subsequent to long-standing back-pressure and infection or, as is more frequently the case, the condition is primarily one of true nephritis in which no improvement can be expected.

(*c*) *Acidosis.*—In cases of impending renal failure (uremia) it is not unusual to find, in addition to the nitrogenous elements, a marked retention of acid salts which are normally excreted by the kidney. The degree of acidosis may be determined by ascertaining the hydrogen

ion concentration of the blood or by the estimation of the carbon dioxid content of the alveolar air. Another simpler though somewhat inaccurate method is the determination of the amount of sodium bicarbonate required to render the urine alkaline. The change in urinary reaction normally occurs in a few hours after the ingestion of 10 gm. of the alkali.

Preliminary Treatment.—This may be classified as follows:

(*a*) *Relief of Urinary Retention.*—In the majority of cases showing evidence of renal insufficiency the condition is secondary to urinary back-pressure. The treatment is, therefore, directed toward relief of the retention, and catheter drainage of the bladder is the rule. A retention catheter is most frequently employed, the bladder being irrigated twice daily with 1 : 60,000 mercuric chlorid, followed in some cases by the introduction of 10 per cent. argyrol. The catheter is removed at the end of three days, allowed to remain out from four to six hours, during which time an injection of 5 per cent. argyrol is given, and then the catheter is reinserted. These patients, for the most part, are up and about the ward, the catheter being plugged with a cork, which is removed at intervals of from two to three hours and the bladder emptied. In some cases with very reduced function the catheter is connected for continuous drainage. In the event of the development of pronounced urethritis, epididymitis, or in cases in which the retention catheter is not tolerated, two courses are open: catheterization at intervals of from four to six hours or, in rare cases where this is impracticable, suprapubic cystostomy.

In speaking of catheterization we must not neglect to caution the physician against the single use of a catheter for diagnostic purposes —to see if residual urine is present, etc.—unless he is prepared to follow it up by regular catheterization. A patient who has voided fairly well up to that moment may never urinate naturally again, and unless a physician is at hand with a proper and varied set of catheters (especially coudé gum catheters) dire results may happen. The toll of deaths yearly from the failure to recognize these facts must be large. When a large residual urine (400 c.c. or over) is encountered, systematic catheterization two or three times a day should be carried out, even though the phenolsulphonephthalein test be good, as a crisis (uremia or infection) may occur at any moment.

(*b*) *Diuresis.*—Throughout the course of the preliminary treatment large amounts of water are given, each patient receiving at least 6 ounces every hour during the day and the same amount at two or three hourly intervals at night. The total daily intake of water, therefore, exceeds 3 quarts.

The insistence on water in large amounts by mouth, and if necessary by rectum, infusion and transfusion, has been our practice for many years, since our report of a remarkable case in which the use of huge amounts of water by every route was followed by great improvement.[8] Since then many apparently irredeemable cases have been brought through the crisis and have come finally to a successful operation.

We may mention one case, a man aged eighty-four, uremic, with a residual urine of 1500 c.c., whose kidneys were so badly impaired by back pressure that only a trace of phenolsulphonephthalein came through in four hours, who, under forced water and catheter drainage for six weeks, finally put out 31 per cent. phenosulplhonephthalein in one hour and went through perineal prostatectomy successfully.

(*c*) *Urinary Antiseptics.*—Of the internal urinary antiseptics in general use, hexamethylenamin is perhaps the best. This, however, is far from being ideal, and in many cases its value is questionable. As is well known, its action depends on its conversion into formaldehyd, and this occurs only in a urine whose reaction is definitely acid. In alkaline urine it is valueless, and in these cases it is wise to discontinue its use until the urine can be rendered acid by the use of sodium acid phosphate or sodium benzoate.

(*d*) *Treatment of Acidosis.*—In the acidosis accompanying the severer forms of renal destruction sodium bicarbonate should be given in large doses until the urine becomes definitely alkaline. This may be given by mouth or by rectum, but in the advanced cases the best results follow its use intravenously. Glucose and lactose, the former by infusion, the latter by rectum, also form valuable adjuncts in the treatment of these cases. In these cases and others showing cumulative phenomena free catharsis is often followed by most beneficial results.

II. *Cases with Cardiac Lesions.*—The determination of the cardiac risk often involves careful and prolonged study. Valvular and myocardial change is often seen in these cases, but so long as the condition is fully compensated the risk of operation is minimal. Where there are signs and symptoms of a break in cardiac compensation, however, operation is absolutely contraindicated and should not be considered until complete restoration of function has been established.

III. *Cases with Cardiorenal Disease.*—The study of cardiorenal disease resolves itself into a determination of the relative responsibility of the heart or kidney for the clinical and laboratory findings. As has been pointed out in pure cardiac disease the impairment of renal function may be the result of passive congestion, and if compensation is established the renal function returns to normal. In these cases, in which the cardiac disease is alone at fault, the phenolsulphonephthalein output is rarely alarmingly low, nor is the retention of urea much above the upper limits of normal. Where the burden of responsibility rests with the kidney, however, its functional value, as determined by phenolsulphonephthalein, may approach zero, and the urea retention may be at a very high level. Marked improvement as regards the renal and cardiac condition may follow promptly the institution of catheter drainage and other preliminary measures.

In other cases giving little or no evidence of urinary retention, where the elements of back pressure and infection can be eliminated, changes in renal function fail to keep pace with cardiac improvement, and the condition is one of true nephritis.

The question to decide in the treatment of these cases is the factor

primarily responsible for the condition. If the cardiac disease is primary. rest in bed, courses of digitalis, and in some cases limitation of the fluid intake may bring about return of compensation. In the cases in which the preponderance of fault lies with the kidney, the establishment of free urinary drainage, diuresis, regulation of the diet, and, in the event of urea retention, free catharsis may be of benefit.

V. *Cases with Infection.*—The majority of patients requiring operation for the relief of prostatic obstruction have urinary infection, and in a recent series of 94 cases, the urine of 66, or 70 per cent., contained pus and micro-organisms. The mere presence of bacteria in the urine without localizing signs is not alarming, but the occurrence of an acute process cannot be watched too carefully. Acute infections of the epididymis immediately call for a suspension in the use of the retention catheter.

Results.—As a fair statement of what can be accomplished by means of careful preparatory treatment we think we may take the first year's work in the Brady Urological Institute from January, 1915 to January, 1916. During this time there were 94 cases in which prostatectomy was carried out, 90 by the perineal route and 4 suprapubically, with only one death, this patient being ninety-three years of age and dying of cerebral thrombosis on the thirteenth day after operation. An analysis of these cases is as follows: The average age was sixty-seven, the youngest forty-six, and the oldest ninety-three years of age. There were 3 over eighty, 15 over seventy-five, 23 over seventy. During this period every patient who came to the hospital suffering with pronounced obstruction from prostatic hypertrophy was operated on, so that there was no selection of cases; fifty-three cases required considerable preliminary treatment, the longest being a period of sixty days; 5 cases required preliminary treatment over four weeks; 9, over three weeks; 23, over two weeks; 39, over one week, and 11, less than one week. The following analysis of the phenolsulphonephthalein records shows the splendid improvement which was obtained by means of preparatory treatment.

In the series of 94 cases, 51, or 54 per cent., required preliminary catheter treatment, and of these, 30 showed on admission an output of less than 30 per cent. phenolsulphonephthalein for the first hour, and 19 an output of less than 20 per cent. The preparatory treatment caried from four to sixty days, and at the time of operation of these 30 cases only 10 had a first hour phenolsulphonephthalein of less than 30 per cent., and ony one less than 20 per cent.

There were numerous cardiac lesions found in this series, both myocardial and valvular in character, and two extremely severe—one, a man seventy-five years of age, with a very bad heart from myocarditis, and another aged sixty-six, whose case has been cited above. In regard to the cardiac cases we may say that almost every case, even those of very severe degree, can finally be got in sufficiently good condition for perineal prostatectomy under ether anesthesia, this anesthetic on account of its stimulating effect being preferable to anything else

in cardiac cases, but gas is preferable in other cases. We are firmly convinced that these patients need not be operated on by spinal anesthesia.

High blood-pressure was moderately common in this series of 94 cases, there being 42 over 150 and 15 over 170. In 4 cases the blood-pressure was 200 or more, yet operation was successfully performed in each of these cases. In 2 recent cases the blood-pressure reached 285 during operation. Considerable care was taken in preliminary treatment in these cases, as described above.

A survey of these 94 patients, many of whom were very aged and infirm, shows that with proper care perineal prostatectomy may, indeed, be called a benign operation. This, we believe, is due to various facts: The wound is extravesical, the drainage dependent, and the absorption of septic materials unquestionably less. Abdominal distention and other complications, which are not infrequently present after suprapubic prostatectomy, are very much less frequent after the perineal operation. The ability of the patient to get out of bed in a very few days, and the ease with which hemorrhage can be controlled, either by ligation at operation or by packing, are very greatly in favor of the perineal route. These facts are mentioned because we believe that in severe cases the choice of operation has almost as much to do with the ultimate result, particularly the mortality, as the preliminary treatment.

The Question of Preliminary Suprapubic Drainage and Suprapubic Technic.—Gardner[9] is a strong advocate of the "two-stage suprapubic operation." He says: "It has been our practice the day after a patient enters the hospital to perform the primary suprapubic cystotomy under infiltration anesthsia with procain. The patient is given from $\frac{1}{6}$ to $\frac{1}{3}$ grain of pantopon (pantopium hydrochloricum) an hour before the operation. Because of the necessity of anesthetizing each layer, the primary operation occupies a longer time than if the patient was under general anesthesia. But the patient is not suffering from any shock, and we have a chance to prepare the tract for our second operation, taking care to open the bladder as high up as possible. All this time the prostate may be examined and our cystoscopic findings checked up. A large mushroom catheter is placed in the suprapubic wound for drainage, and a purse-string suture makes a tight joint. The fascia and skin are sewed up in layers. Two days after the operation the patient is out of bed. These old men do not do well lying down.

"Following the primary cystostomy, the functional test frequently makes a marked drop, and then after a day or so begins to rebound again, demonstrating the advantage of dividing the shock in two parts. As the general condition improves, incidentally his phenolsulphonephthalein output is improved, and he is prepared for the second operation.

"At the time of the second operation a general anesthesia of ten minutes suffices to stretch up the original opening and lift out the adenomatous prostate. The Hagner bag controls what little hemorrhage there is, and a large drainage-tube of the Marion type is used in

the suprapubic wound. The Hagner bag and the Marion tube are removed at the end of forty-eight hours. The bottle-pump designed by Bethune is then used. The wound is kept dry by this method and heals very rapidly. Usually after a week's use the opening is so small that the catheter attached to the pump may be removed, and the wound heals spontaneously. An indwelling catheter placed in the urethra for a few days assists in the final healing. The patient sits up in bed the second day and is permitted to get out of bed the following day. It requires from three to four weeks for the average suprapubic wound to heal."

"Standardization of Methods in Cases of Prostatic Obstruction."—This is the title of a splendid paper by Quinby[10] which every one should read. After describing briefly but systematically the preliminary treatment and necessary tests, he says:

"Two ways of reaching the prostate exist—through the perineum and transvesically—and while it is not our purpose to describe these operations in detail here, it will be necessary to give a brief outline of each, especially as regards its applicability under differing conditions.

"*The Perineal Operation.*—The earliest operations for the removal of the prostate followed the perineal approach, and although many difficulties were experienced by the pioneer operators, this approach as modified by several surgeons, especially Young, is still of great value and should be the method of choice in many instances.

"The two outstanding advantages of the perineal operation as compared with the suprapubic lie in the control of hemorrhage and in the easy and short convalescence. The gland having been removed, there is left a cavity external to the bladder itself which can be nicely and accurately packed with gauze in a manner quite impossible when the approach has been transvesical. Also, for reasons not always quite clear, this form of operation is well known from clinical experience to cause less immediate prostration to the patient. Each of these points always plays a part in promoting a quick, relatively comfortable convalescence.

"A still further and very important advantage of the perineal operation is in regard to the question of malignancy. The incidence of prostatic cancer is unfortunately quite high, some clinics finding it in as much as 20 per cent. of their cases. This is probably a greater proportion than that seen, as a rule. In our own experience about one of each 8 or 10 cases is found to be malignant. The malignancy always begins in the posterior lobe, that portion of the gland which is seen first and examined by the perineal operation, but not seen at all by the transvesical approach. In any case, therefore, where the least suspicion of malignancy has been raised by the clinical examination, operative investigation of the gland from its perineal aspect is imperative.

"The most marked disadvantage of the perineal approach lies in the fact that it is a relatively difficult operation in the hands of whose who have not given special attention to perfecting themselves in it in all its details. The anatomic proximity of the prostate to the rectum has

sometimes led to wounds of this structure and subsequent fistula. In other instances opening the urethra at a point too far below the tip of the prostate, and thus cutting the external or voluntary sphincter, has led to incontinence, partial or complete. Furthermore, unless the operator has been able to make a careful cystoscopic survey of the prostate before operation he may overlook a hypertrophied middle lobe by the perineal route, and find his patient after the operation still unable to empty the bladder with success in spite of the fact that the prostate has been removed. I have personally seen instances of each of these difficulties.

"For certain reasons [occasional injury of rectum and external sphincter] the perineal operation has failed to gain in popularity in the eyes of many surgeons That this lack of popularity is undeserved I am sure everyone will quickly admit should he have the opportunity to follow to the end-result a series of cases of prostatectomy performed by this route and to compare this with a like series done by the suprapubic method. The situation may be fairly summed up by the statement that the perineal operation is harder on the surgeon than the suprapubic, but easier on the patient.

"To overcome the difficulties of the perineal operation three things are necessary: (1) The surgeon himself must be able to use the cystoscope and to *understand what he sees;* (2) he must know the antomy of the perineum accurately, both in the cadaver and in the living patient; (3) he must have the operating room facilities for placing his patient in the high lithotomy position, which can only be secured by the use of a board such as that devised by Professor Halsted, since no operating table yet on the market will give sufficient elevation. The exaggerated position is absolutely essential, since it puts the perineal structures on the stretch and makes it possible to do the whole operation under the guidance of the eye. Only too often have I seen a surgeon vaguely operating in the depths of a perineal wound, unable to see, uncomfortable, and uncertain of just what structures or portions thereof were being removed, and all the difficulty due to the fact that he had his patient in the low lithotomy position, such as is used for a curetage of the uterus, or the removal of hemorrhoids."

The Suprapubic Operation.—"In any considerable number of patients suffering from prostatism in whom it is imperative that the bladder can be put at rest and the kidneys relieved, there will be found not infrequently cases that cannot tolerate an inlying urethral catheter. The reason for this is usually found in an acute infection of the prostate and prostatic urethra coexisting with enlargement. In the hands of a skilful, especially trained orderly or nurse such cases can be tided over the acute discomfort to a stage in which the catheter is satisfactorily tolerated. Repeated ill-advised manipulations with frequent prodding by catheters of varying sorts make for increase of infection and irritability of the already swollen prostate. Under the circumstances the bladder should be opened above the pubes forthwith.

"The suprapubic operation will also appeal strongly to those surgeons

who are not familiar with the use of the cystoscope as a means of preoperative diagnosis. With the bladder open they can see definitely that with which they must deal. Another group of surgeons, entirely unfamiliar with the proper type of perineal operation, will naturally choose the easier operation.

"But leaving such instances aside, and omitting from consideration prostatic malignancy, let us ask the nature of the disadvantages of the suprapubic operation. To my mind there are two: a major one and a minor one.

"The first of these concerns the control of the hemorrhage after enucleation has been performed. One has but to review the several devices and methods still employed to appreciate quickly that there is no one of them in general favor. One surgeon uses pressure by the Hagner bag or a modification of this; another packs the cavity with gauze for a longer or shorter time; still others employ sutures or ligatures. The truth is, that the mechanical situation which leaves a cavity containing torn vessels, often of considerable size, uncontrolled at the most dependent portion of the bladder, which must inevitably contain urine and often bacteria, and which must be drained against gravity, is inconsistent with the laws of sound surgical practice. The danger of postoperative hemorrhage is, therefore, an ever-present one, for the prevention of which measures should always be carefully taken.

"The second disadvantage of the suprapubic operation concerns, as a rule, only those cases which have the so-called two-stage operation, and that is, of imperfect and slow healing of the twice-opened wound through the abdominal wall and bladder. The constant presence of dressings saturated with urine, unless some special means be employed to avoid this, is also often extremely distasteful to patients of a certain type.

"I wish strongly to advocate that all those bleeding points which remain after enucleation of the prostate be controlled by accurate ligatures of plain catgut passed on a curved needle. Naturally, such a procedure adds a few minutes to the duration of the operation, but are well worth the extra time. It is thus seen that the practices of the 'five-minute' prostatectomist are to be entirely condemned."

In an important article by Judd[11] the surgery of the prostate is discussed at length, but lack of space prevents more than a few quotations. Judd considers the transvesical operation technically easier and not likely to be followed by injury of the rectum and permanent fistula:

"If the perineal operation has any advantage over the transvesical it is in the lessened liability to infection. The tissues in the perineum are less susceptible to infection than are those in the prevesical space. Infection is such an important consideration in these cases that it is necessary to resort to the perineal operation with some chance of an unsatisfactory functional result or else to develop a definite transvesical technic, which, with the aid of other improvements, will control the factor of infection.

"A two-step operation has been advocated by some surgeons because of the importance of avoiding infection. I do not believe this is

often necessary or advisable. It is most important to carry out preliminary preparation in a large percentage of the cases, a measure which has done more for the surgery of the prostate than any other one factor. Preparation consists in ridding the patient of residual urine, cleaning up the infection, and increasing resistance as much as possible. The withdrawal of residual urine and the preparation of the bladder by the use of the urethral catheter is preferable to preliminary drainage of the bladder through the prevesical space. In some cases it is impossible to pass a catheter, and in others large stones in the bladder may complicate the condition, so that it may occasionally be necessary to perform the operation in two steps. Serious conditions may arise and seemingly unfortunate results follow urethral catheterization, though I feel certain that there will be much more frequent and more serious trouble following the drainage through a suprapubic incision. After the bladder has been opened and drained, and a sinus has persisted for some time, it is difficult to do an accurate operation through the opening without greatly enlarging it, and if the opening is enlarged the other tissues are immediately exposed to infection. If the gland is large, it may require considerable extension of the incision in order to remove it. If a drainage operation has been performed previously, the prevesical tissues will be firm and resistant and it may be difficult to reach the lower part of the enlargement."

"Judd advocates the use of a colon bacillus vaccine, and in support of this advice gives the following table of complications:

	Vaccine, 23 patients.	No vaccine, 23 patients.
Cases of epididymitis	2	5
Cases of pyelonephritis	1	5
Cases of phlebitis	0	1
Weeks of preoperative treatment	5.5	3

"The following is a review of the patients operated on by us between January, 1, 1917 and August 24, 1917:

Patients	84
Adenomatous hypertrophy and prostatitis	78
Carcinoma of the prostate	4
Drainage preliminary to prostatectomy	10
(Nine under cocain and one under ether)	
Deaths following preliminary drainage (suprapubic)	2
Two-stage operation	8
Deaths following drainage and prostatectomy	1
Perineal prostatectomy	1
Primary suprapubic cystostomy for prostatectomy	73
Prostatectomy with removal of stone	5
(Uneventful convalescence; bladder drainage in all)	
Prostatectomy (diverticulum of the bladder)	4
Diverticulum and prostate removed simultaneously	2
Diverticulum not removed at the time of prostatectomy or subsequently	2

The Vesical Orifice Following Prostatectomy.—During the past ten years articles have appeared on this question by Wallace, Thomp-

son, Walter, Freyer, Wade, Hyman, and Watson. Watson's paper is of much interest and will be quoted, as follows:

"Hyman[5] in 1914 presented a very comprehensive study of the normal bladder and its sphincters, and particularly the changes that were brought about at the orifice following suprapubic prostatectomy. His work was done by means of readiographs taken of the normal bladder and of the bladder in cases of prostatic hypertrophy before and at varying intervals after operation. In his work he used a 5 per cent. solution of collargol introduced into the bladder through a catheter which was withdrawn before the radiograph was taken. In all of his normal bladders the internal sphincter was found to be the point of closure. This was also the case in prostatic hypertrophy previous to operation.

"Of 38 cases studied after suprapubic prostatectomy, Hyman found that 28 showed two distinct cavities, the bladder cavity and continuous

Fig. 448.—Cystogram Nine Months After Suprapubic Prostatectomy Showing Dilated Vesical Orifice and Funnel-shaped Urethra. (Hyman, "Ann. Surg.," 59, 1914.)

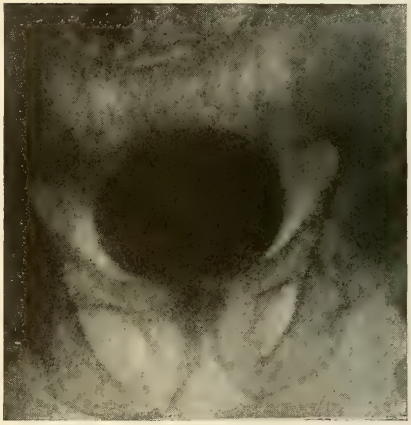

Fig. 449.—Cystogram Five Years After Suprapubic Prostatectomy Showing Dilated Vesical Orifice and Cavity Below and Continuous with Bladder. (Hyman, "Ann. Surg.," 59, 1914.)

with it the one resulting from the removal of the adenomatous portion of the prostate. A few of the remaining showed only a very slight funnel formation in the region of the prostatic urethra continuous with the bladder cavity and the rest showed no change from the normal. He concluded that the internal sphincter marked the site of closure in the normal bladder and also in the bladder of prostatic hypertrophy. After suprapubic prostatectomy, however, the external sphincter or compressor urethra forms the point of bladder closure in the majority of cases, the internal sphincter or normal closing muscle of the bladder having been destroyed or rendered useless by operation. He further concluded that the interval after operation made no difference in the relaxed condition of the internal sphincter.

"In view of the almost uniform dilatation of the internal sphincter following suprapubic prostatectomy it seemed interesting to investigate

the condition of this region following the operation by the perineal route. For this study 25 cases, varying from thirteen years to three weeks since operation, were taken at random from Brady Urological Institute.

"In the study of 25 cases in no instance did the internal sphincter remain permanently dilated, and it seems probable that following perineal prostatectomy the musculature about the vesical orifice becomes readjusted in the vast majoirty of cases. This occurs in some instances as early as the third week after operation and probably remains so throughout life, as shown in one of the cases in which internal sphincter was functioning normally thirteen years after operation.

"From the observations of Wallace and Hyman it has been shown that in most cases of suprapubic prostatectomy the internal sphincter is

FIG. 450.—CYSTOGRAM THREE WEEKS AFTER PERINEAL PROSTATECTOMY SHOWING NO DILATATION OF INTERNAL SPHINCTER. (Watson, "Jour. Urol.," Vol. I, No. 6.)

so damaged that it is useless as a sphincter muscle, and thereafter the external sphincter forms the closing point of the bladder. Following this operation there is usually no incontinence and the external sphincter is apparently adequate for a condition of perfect urinary continence.

"Following perineal prostatectomy the point of the bladder closure is at its normal site in every instance, *i. e.*, the internal sphincter. This returns to normal in some cases less than one month after operation and even earlier, judging from the clinical evidence of urinary continence of one to two hours' duration a few days after perineal prostatectomy in the membraneous urethra, back of the external sphincter."

Mortality After Prostatectomy.—In an interesting article Deaver[12] has presented statistics in regard to the mortality after prostatectomy and the method which should be adopted to prevent it. I will quote from him at length:

"In 1905 Whiteside reported that the average mortality among many American prostatectomists was 20 per cent., with only 30 per cent. of complete cures. A similar study was made in 1915, in which the work of 34 surgeons was recorded, giving data on 1432 cases. In this latter series about half of the surgeons submitting reports operated on considerably more than half of the 1423 cases. These are the men of wide experience and the mortality rate in their work is less than 3 per cent., in contrast to a mortality rate of 26 per cent., as reported by the less experienced operators.

"As regards postoperative mortality the percentage incidence has fallen from a general average of 70 per cent. in 1905 to 19 per cent. in 1915, while among the more experienced operators it was but 7 per cent. according to the more recent figures.

"The same is true among English surgeons. In the first series of 100 cases operated upon by Freyer the mortality rate was 10 per cent.; in his last cases it was only 3 per cent., with a general average among 1000 cases of 5.5 per cent. About the time when Freyer's mortality was slightly over 6 per cent. (1908) C. M. Page collected statistics from the records of four London hospitals for the corresponding years and found the mortality rate to be 21.5 per cent. Wade reports a mortality rate of 35.4 per cent. from one of the largest hospitals in Scotland for the same period, and states that during the years 1906 to 1910 69 patients were subjected to prostatectomy in St. Thomas' Hospital of London, of whom 14 died, giving a mortality record of 20.3 per cent.

"In the first place, *it is inadvisable to do an immediate cystostomy in individuals whose resistance is far below par* when there is possibility of improving their condition up to a certain point by non-operative measures. This class is made up largely of patients with long-standing obstruction, whose bladders are markedly dilated, and with large quantitites of residual urine, and in whom the catheter has seldom, if ever, been used. Uremia is so often impending in patients of this kind that the anesthesia of itself is too great a risk to assume. Under these circumstances gradual decompression of the kidneys is accomplished by catheterization, either intermittent or continuous, and it will be found that improvement frequently follows up to a certain point and there becomes stationary. The question then arises of doing either a preliminary cystostomy or proceeding at once to enucleation of the prostate. In all doubtful cases of this kind we favor the two-stage operation. *Whiteside in his prognostic studies has failed to show that preliminary bladder drainage decreases the mortality of prostatectomy*, although it is our experience that many patients, especially those belonging to the group under discussion, can be safely operated on only in this manner.

"In the presence of violent infection with marked concentric hypertrophy of the bladder walls and greatly diminished capacity with little or no residual urine, the subjects of which are usually in wretched general health and the victims of early renal infection, cystostomy should be done immediately if, indeed, any operation is justifiable. The mortality in this class of cases is high, whatever line of treatment is followed,

but it has been our experience that prolonged suprapubic drainage serves to bring a majority of them to a condition of operability. If rapid and clean enucleation of the prostate is then done, the chances of curing the patient are fair. Pyonephrosis, usually unilateral, is so frequent an occurrence that to advise prostatectomy without a knowledge of the differential kidney function is unwarranted.

"A third group of cases that calls for special preoperative consideration includes beginning hypertrophies, incipient not only as regards its secondary effects on the bladder, kidneys, and cardiovascular system. I can see no rationality in doing a two-stage operation when the reasons for which the first stage—*i. e.*, suprapubic cystostomy—is usually done are wanting.

"The functional tests should be employed and should be repeated often during the preliminary treatment so as to obtain a concise idea of the recuperative power of the renal tissue under treatment. The time to operate is when the level of maximum function is attained and maintained under the routine of hospital treatment. Mortality records are written from the group in which such attainment is impossible; rarely does a patient die whose renal function has promptly responded to preoperative therapeusis."

In a discussion before the Basel Medical Society June, 1917 Wilbolz stated that in a series of 150 perineal prostatectomies the mortality had only been 5 per cent., while in 40 suprapubic operations his mortality had been 25 per cent. He considered the opportunity to stop hemorrhage, dependent drainage, and the avoidance of abdominal complications, intestinal obstruction, pain on coughing, and the ability to get the patient out of bed quickly with less absorption from the wound, important factors in favor of perineal prostatectomy. He considered particularly that the frequency of carcinoma was a very important item in favor of the perineal route, and mentioned cases in which he had carried out complete excision of the carcinomatous prostate and the patient was still alive and well four to six years afterward.

Ultimate Results of Prostatectomy.—Martin[13] gives a detailed study of the end-results of 55 cases of suprapubic prostatectomy and 55 cases of perineal prostatectomy. These statistics, collected from family physicians, are taken to show the great superiority of the suprapubic route. In view of the fact that no information is given as to the character of the perineal operation performed, when it is well known that the results obtained by the old meeian line perineal incision, with enucleation of the prostate through the triangular ligament and internal sphincter, which has been so commonly practised in America, gives results which are infinitely inferior to those obtained by the careful exposure of the prostate through the perineum back of the triangular ligament and enucleation of the prostate conservatively with preservation of the ejaculatory ducts and internal sphincter.

In order that the surgical world may not be too hasty in accepting such figures as just condemnation of the perineal route I have reverted to a detailed report of 450 cases made by me to the International Con-

gress of Medicine in London in 1911, and have placed these alongside of Martin's statistics.

Closure of Wound.

	Martin, 110 cases. Suprapubic.		Martin, 110 cases. Perineal.		Young, 450 cases. Perineal.	
	No.	Per cent.	No.	Per cent.	No.	Per cent
Healed within four weeks	30	61.2	21	42	288	68.8
Healed within three months	16	93.8	12	66	78	91
Healed within one year	3	100	9	84	27	97.7
Sinus closing after one year	..	...	5	10	4	1
Permanent fistula	..	...	3	6	5	1.4

A further study of my cases showed that in 18 cases the fistula closed within one week and 50 per cent. were healed in less than twenty-one days. One patient went home with fistula closed on the sixth day after operation (a physician).

Martin says, "from my questionnaire I received definite information on urination in 37 suprapubic and 36 perineal patients."

These results are summarized in the following table, to which I have added my own statistics:

Martin—present frequency of urination in 73 cases. Young—331 cases heard from.

	Martin		Young
Day:	Suprapubic.	Perineal.	Perineal.
Normal	30	24	290
Two hours	5	10	36
One hour	1	2	13
Thirty minutes	1	0	1
Night:			
Do not arise at all	13	1	72
Arise once or twice	16	16	158
Arise three times	2	9	30
Arise oftener than three times	4	12	3

Results expressed in per cent.—Martin and Young.

	Martin				Young	
	Suprapubic.		Perineal.		Perineal.	
	Day, per cent.	Night, per cent.	Day, per cent.	Night, per cent.	Day, per cent.	Night, per cent.
Good	81	82.8	66.6	44.7	85	69
Fair	13.5	5.7	27.7	23.7	11	9.1
Poor	5.4	11.5	5.5	31.5	4	1

In my statistics, which are given in much greater detail, the word "normal" was used by only a few patients in their reply. I have here classed in this first group those in which the interval was three hours or more during the day. The same applies to the replies in regard to voiding at night. As a rule the interval in hours was given, and I have therefore classed as none at night where the patient went six hours or over, as almost all old men normally get up once toward morning.

Although 70 per cent. of the patients employed a catheter before operation, less than 1 per cent. have had to return to a catheter life. (Four cases, all of the small sclerotic type of prostate before operation. A punch operation would have been the operation to perform in these cases.)

Martin says that "when we bear in mind the almost intolerable suffering that is consequent on an incontinent bladder efforts to preserve the integrity of its function seem entitled to the most urgent consideration. Concerning this phase of our subject I have definite information of 46 suprapubic and 50 perineal cases which is summarized in the following table" (to which I have added my own statistics):

Control of Bladder.

	Martin.				Young, 433 cases.	
	Suprapubic, 46.		Perineal, 50.		Perineal.	
	No.	Per cent.	No.	Per cent.	No.	Per cent.
Full control	37	80.5	32	64	426	97
Partial control	7	15.2	11	22	7	0.1
Complete incontinence	2	4.3	7	14	0	0

Martin says that "while with the majority of these old men active sexual life has ceased to be a matter of grave concern, yet there are men who, discussing with me the immediate and remote dangers of prostatectomy, inquire seriously into the possibility of damaged sexual function. Hence the figures covering this phase are not without instructive value.

"On this postoperative phase I have information touching on the 33 suprapubic and 33 perineal cases a similarity that makes the figures given in the following table of comparative interest" (Martin):

Effect of Sexual Power.

	Martin.				Young, 133 cases with normal sexual powers.	
	Suprapubic.		Perineal.		Perineal.	
	No.	Per cent.	No.	Per cent.	No.	Per cent.
No change	21	63.6	16	49.5	85	64
Diminished	9	27.3	16	48.5	44	33
Increased	3	9.1	1	3	4	3

In my statistics I have not included cases in which sexual powers were impaired or lost before operation and remain the same after operation. Had I included these cases the number of cases in which sexual powers were the same after operation would be much greater, in fact, 75 per cent.

Among my 450 cases there was one unbroken series of 128 cases of perineal prostatectomy without a death, 2 of the patients being over eighty years of age and 43 over seventy years of age. In the 450 cases the mortality was 3.77 per cent., all but 5 of the deaths occurring after the first week after operation. Most of the deaths were in patients over seventy years of age. There were 292 patients below seventy years operated on, with a mortality of 2.7 per cent.

These figures show, I believe, the benignity of perineal prostatectomy and the well-nigh perfect results which can be obtained from it. The folly of drawing conclusions from a short series of cases performed by several operators is shown by a comparison with woeful results, presented by Martin's series of cases. His conclusions that "measured by end-results, suprapubic prostatectomy is vastly superior to the perineal operation," are certainly not warranted by the above statistics. He has demonstrated an interesting fact that 14 per cent. of the supra-

pubic cases had complete or partial incontinence, a result which has been held as only possible with the perineal route. My statistics show that incontinency can be completely avoided if the perineal operation is correctly done, and the triangular ligament and external sphincter not injured.

The occurrence of complete obliteration of the prostatic space and dense stricture or contracture of the vesical orifice and prostatic urethra which occurs occasionally after suprapubic prostatectomy, as shown by Denslow and others, is not indicated by Martin's report. Denslow's report is as follows:

Recurrence of Urinary Obstruction After Prostatectomy.—Denslow[14] has recently made an interesting report of cases which I will quote:

"In the past few months I have had occasion to reoperate in 5 cases of prostatic obstruction in which a suprapubic prostatectomy had previously been done. One of these cases was one in which I myself had operated. The other operations had been done by men of experience in Kansas City and elsewhere. In two of the cases I assisted the original operator to correct the secondary obstruction. The usual history of these patients was that they had made a good recovery from the operation, had left the hospital in good condition in from four to six weeks, voiding urine well and being apparently cured. From that time on the size of the stream would pregressively diminish, and it would become more difficult to void. Finally, the suprapubic wound would reopen and remain open, and the passage through the urethra become closed, or nearly so.

"In the case in which I had done the original operation the patient had been dilated with sounds up to No. 32 French [this is almost never necessary or advisable in perineal cases] every few days up to the time of leaving the hospital. From the events and from experience with other cases I am now convinced that the tip of the sound never entered the bladder, but that the beak would be rotated in the cavity of the prostate. All five of the cases, with the exception of one in which a second operation had been done previously without relief, presented the same general characteristics; in all of them the prostatic hypertrophy had been completely enucleated, and there was no tissue to be removed at the second operation.

"When hypertrophy of the benign type has occurred, and more especially when the greater part of the enlargement is in the median lobe, the urethra is much elongated by reason of the protrusion of the mass through the sphincter vesicæ and into the lumen of the bladder. The sphincter vesicæ is stretched, but intact, as the growth pushes through it. This leaves the sphincter not at the vesical orifice, as normally found, but somewhat at the outer side of the protruding mass. In the cases under discussion the prostatic hypertrophy had been enulceated without wounding the sphincter. The sphincter had then regained its tone and had come together, forming a sort of tympanum above the cavity of enucleation, and between it and the cavity of the bladder.

"On opening the bladder in one of these cases one finds the vesical orifice represented by a mere dimple on the internal surface of the bladder. With a sound in the urethra it is often quite difficult to push the tip through the opening, even with the aid of a finger in the bladder. The cavity below is frequently of such size that a short-beaked sound may be rotated within it. The questions arise, Why all prostatic enucleations are not followed by this result, and what the remedy is for it? The reason it does not happen in every case is that the traumatism ordinarily incident to enucleation is sufficient to prevent the restoration of the sphincter until the lower bladder segment has become adherent in the prostatic cavity and its mucosa is becoming coapted to that of the urethra. This traumatism, while usually inadvertent, has thus served a good purpose. The way to prevent this very undesirable sequel to an otherwise successful operation is, therefore, intentionally to divide the sphincter vesicæ at the time of operation, preferably at the lower margin, and not to try to do a purely urethral enucleation, leaving the sphincter intact.

"The remedy for the condition at secondary operation is the same, namely, to divide the sphincter. This division should be to the under or posterior side of the opening, as the orifice is usually drawn well forward toward the symphysis, and the posterior is the thickest side. I have used Young's prostatic punch in making this cut, but think division by cutting and divulsion to be as efficacious. The secondary operation should be followed by systematic dilatation of the bladder neck for at least a year, first weekly, then semimonthly and monthly. This is preferably done with the Kellermann dilator with the Guyon curve, as the beak of this instrument will most certainly go into the bladder.

"The patients on whom a second operation was performed are all in good condition, as far as I know, except one who had been operated on twice before coming into my hands. He healed up well above, but had a weak voluntary sphincter, and has incomplete control of the urethra."

Denslow's opinion as to the desirability of intentional division of the vesical sphincter is at variance with most suprapubic prostatectomists and I have very rarely found it desirable in perineal prostatectomy.

Recto-urethral Fistula.—In Volume IV of Keen's Surgery I discussed at length the operative treatment of recto-urethral fistula and laid stress on the importance of suprapubic drainage to provide a diversion of the urine from the urethra in order to facilitate the closure of the plastic operation upon the fistulæ through the perineum. By this method I had a number of very successful cases, but there were others in which the rectal wound broke down, and on this account a more radical procedure was sought for. In conjunction with Dr. Harvey B. Stone[15] a combined operation was divised in 1913 and carried out in a series of cases with remarkably satisfactory results. The condition present and the operative problem is shown well in Fig. 451.

The operation may be described briefly as follows: First suprapubic drainage of the bladder is established, with the patient in the dorsal posture. The patient is then shifted to the exaggerated lithotomy position. A racquet-shaped incision, beginning in the midline of the

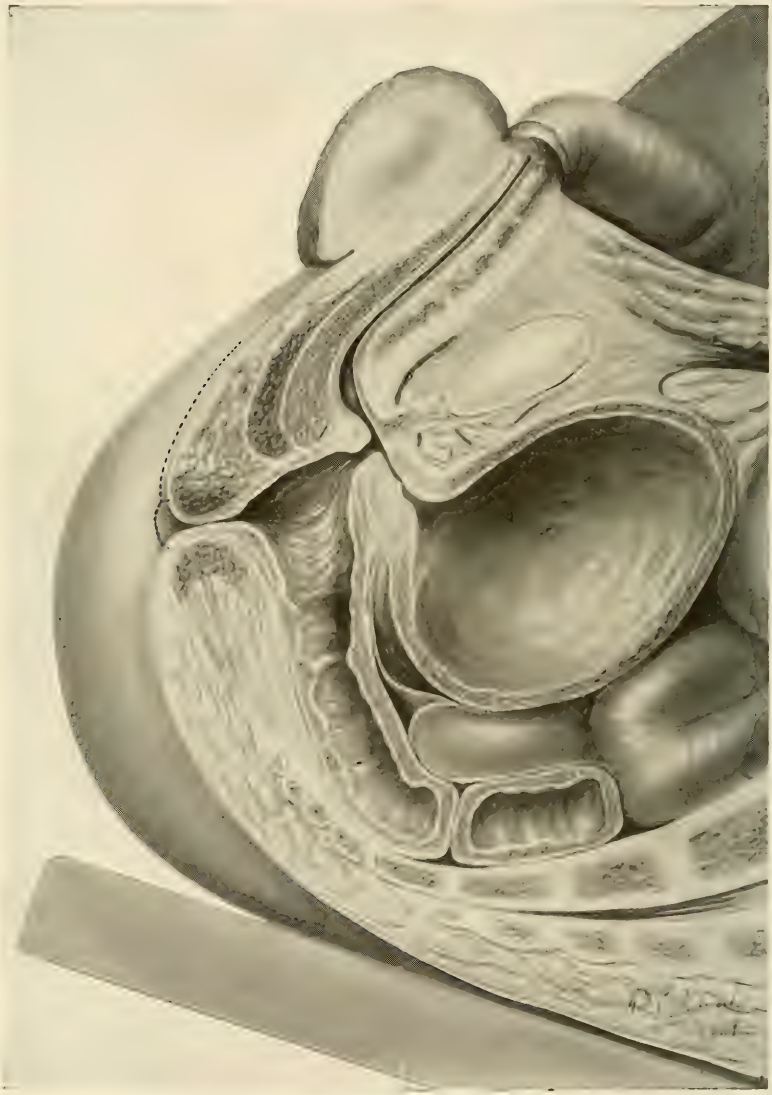

Fig. 451.—The Usual Condition Present in Recto-urethral Fistula.
Dotted line showing the line of incision for the radical cure.

perineum about 3 cm. anterior to the anal margin, is carried backward to this margin, and then encircles it at the mucocutaneous juncture (Fig. 452). Through the circular part of this incision the mucosa of the rectum is dissected free all around until a cylinder of the membrane

FIG. 452.—RACKET-SHAPED INCISION AT ANAL MUCOCUTANEOUS JUNCTURE AND ALONG MIDLINE OF THE PERINEUM.

FIG. 453.—RECTAL CUFF DISSECTED FREE ABOVE POINT OF FISTULA.
Anal sphincter shown divided.

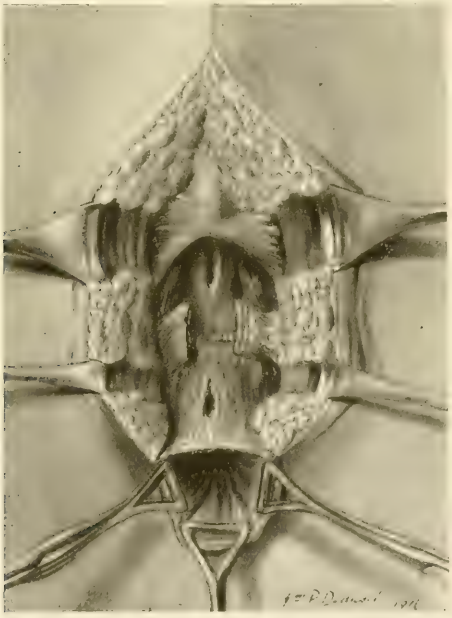

FIG. 454.—STAGE OF THE OPERATION FOR THE RADICAL CURE OF RECTO-URETHRAL FISTULA.
The rectum and urethra have been separated, and the former dissected free and pulled down, showing a fistulous opening in each. This picture shows the sphincter ani temporarily divided, which procedure was not found necessary in the operation upon Case II.

is stripped from its attachments well above the point at which the rectal orifice of the fistula opens, the fistulous tract being divided transversely

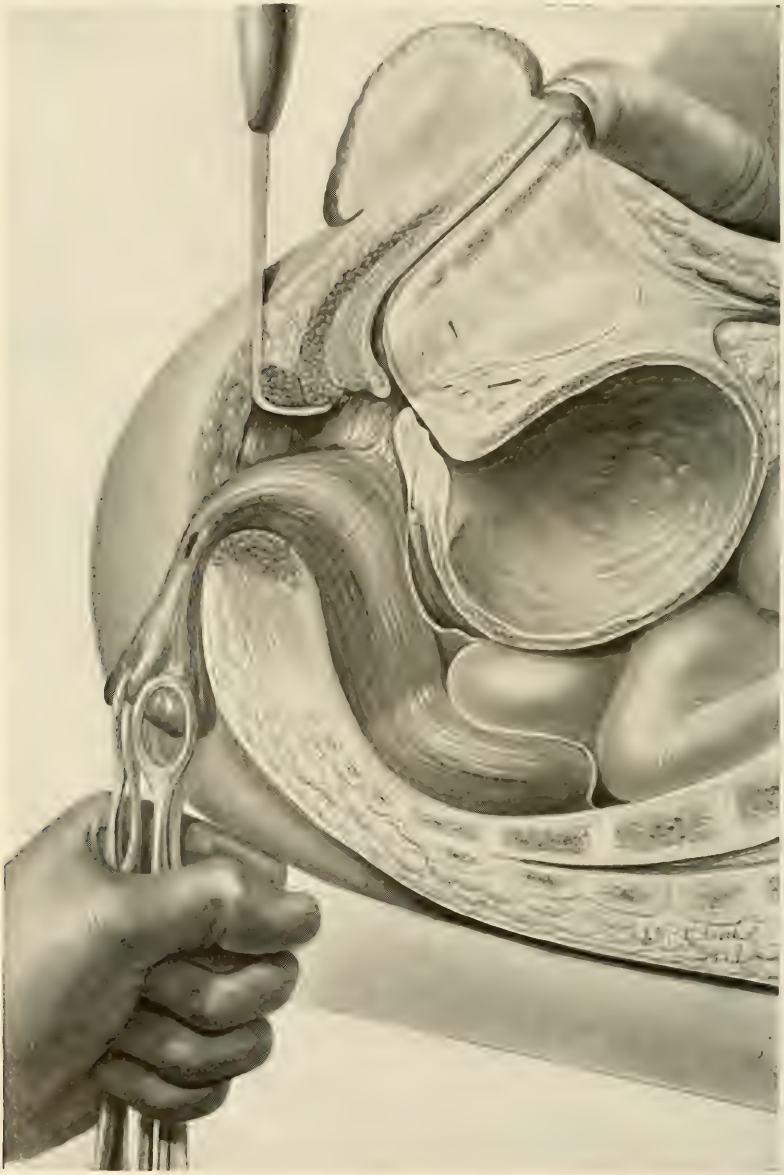

FIG. 455.—LONGITUDINAL SECTION SHOWING THE CONDITIONS PRESENT WHEN THE RECTUM HAS BEEN DISSECTED FREE HIGH ENOUGH TO DRAW THE FISTULA IN THE RECTUM OUT BEYOND THE SKIN MARGIN.

in this process (Fig. 453). This dissection of the bowel is carried upward until sufficient mucous membrane is loosened to permit the pulling of the segment containing the fistulous orifice well out of the anus, the

orifice and a small origin of normal mucosa above it, and all that below it, lying outside the level of the skin and later being excised. This part of the procedure may be described as an exaggeration of the Whitehead principle in operating for hemorrhoids.

A minor point of some practical importance consists in beginning the dissection of the mucosa at the posterior or dorsal part of the circle. Not only is it easier to find normal planes of cleavage here, where there is no scarring, but the field is less obscured by hemorrhage than would be

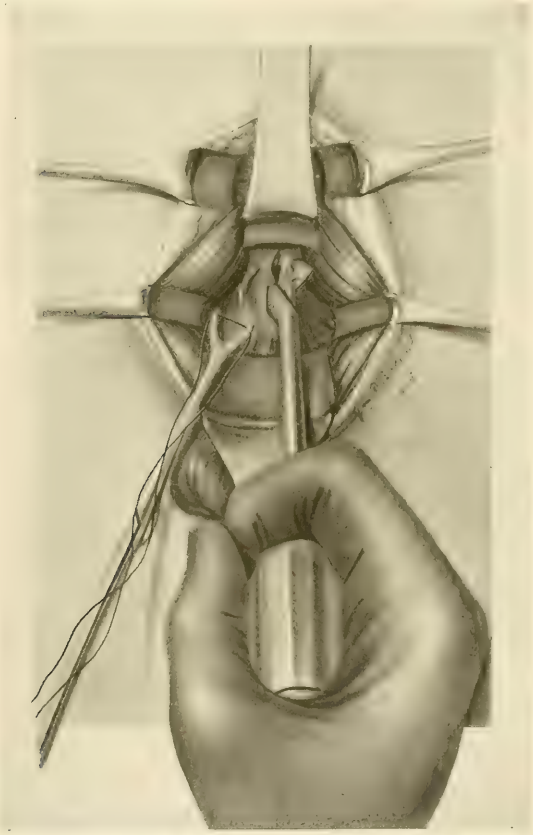

FIG. 456.—CLOSURE OF URETHRAL FISTULA BY MEANS OF THE "BOOMERANG" NEEDLE-HOLDER.

the case if the anterior side is first attacked, as blood then runs down over the posterior half of the wound.

Next, the structures of the perineal body are divided through the straight incision of the midline—the handle of the racquet—so as to expose thoroughly the urethral orifice of the fistula (Figs. 454, 455). It should be noted here that in the first 3 of our cases the sphincter ani muscle had been cut in the midline anteriorly in previous attempts at cure of the condition, so that this part of the incision actually divided nothing but scar tissue in these cases. This scar tissue in such cases is

dissected away laterally sufficiently to expose the ends of the sphincter ani muscle, the levatores ani, and the lesser muscles of the perineal floor. In the rest of the cases with one exception the intact sphincter ani muscle was divided in the midline anteriorly to allow a better exposure and repair of the urethral opening. The muscle was then repaired as in the first 3 cases. In Case 7 it was not considered necessary to cut the sphincter at all. The edges of the urethral fistulous opening exposed are then freshened and brought together with catgut sutures over a sound which has been previously passed through the urethra, the author's "boomerang" needle holder being of great assistance in this deep suturing (Fig. 456). These sutures do not penetrate the urethral mucous membrane. The levatores, fascia, and smaller muscles are

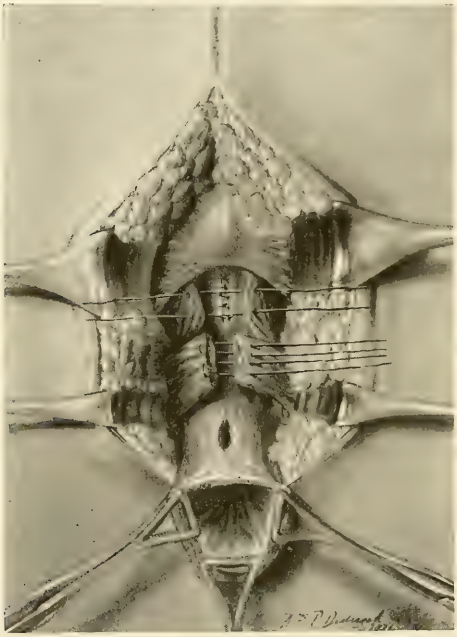

Fig. 457.—Showing Reinforcement of Urethral Sutures Through the Perineal Tissues and Suture of Anal Sphincter (if This Has Been Divided.)

then brought together by interrupted catgut sutures across the midline of the perineum in several layers, reconstructing the perineal body much as is done in gynecologic operations for relaxed vaginal outlet (Fig. 457). Finally, the sphincter ani (if divided) is restored by uniting its ends with a mattress suture of catgut, and the midline incision is closed with interrupted sutures. The last stage in the operation consists in the excision of the protruding cuff of rectal mucosa in which the fistulous opening lies (Fig. 458), and the union of the lower end of the rectal tube to the anal margin of the skin. Figure 459 shows a side view of the entire operation. This is done by interrupted silk sutures after four submucous, sub-cutaneous sutures of catgut have been placed at quadrant points to help anchor the bowel in place.

It will be seen that there are four essential principles in this procedure. The first is the protection of the repair from leakage and muscle-spasm by diverting urine from the urethra through suprapubic drainage. This has been emphazised in the publication of a previous operation for the same purpose by one of us (Young). The second principle is the complete ablation of the damaged portion of the rectal wall and the reposition of perfectly sound mucosa quite to the edge of the skin. The third element in the operation is the closure of the urethral orifice, and the final essential is the interposition between the rectum and the urethra of a solidly built up perineal body. The operation was described in detail with cases in the Jour. of Urol., June, 1917.

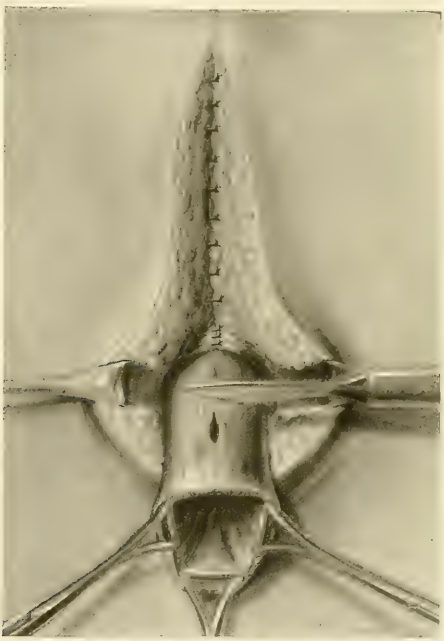

FIG. 458.—AFTER ANCHORING THE RECTUM BY FOUR CARDINAL CHROMICIZED CATGUT STITCHES THE RECTUM IS AMPUTATED JUST ABOVE THE FISTULA.

Eleven cases now have been operated upon and followed for three years or more. The following case is given as an example:

Case III.—Patient aged twenty-three, operated at the age of ten for vesical calculus through the perineum, followed by recto-urethral fistula and rectal incontinence. Four unsuccessful operations to cure fistula and repair sphincter ani. Radical operation March, 1915. Report by letter Dec. 10, 1919: There is no fistula present. I void urine about nine times in twenty-four hours. Sexual powers normal. Result perfect.

These 11 cases presented many difficulties. Many were of long duration with extensive dense cicatrices around the fistulous tract. They had all been subjected to previous operation, several three or four

times. In 3 cases the sphincter ani had been damaged, with resultant incontinence of feces, and in 2 cases there was incontinence of urine. In all of these cases with the exception of 2 the recto-urethral fistula has been cured. The cases of incontinence have also been cured. The two imperfect results are greatly improved.

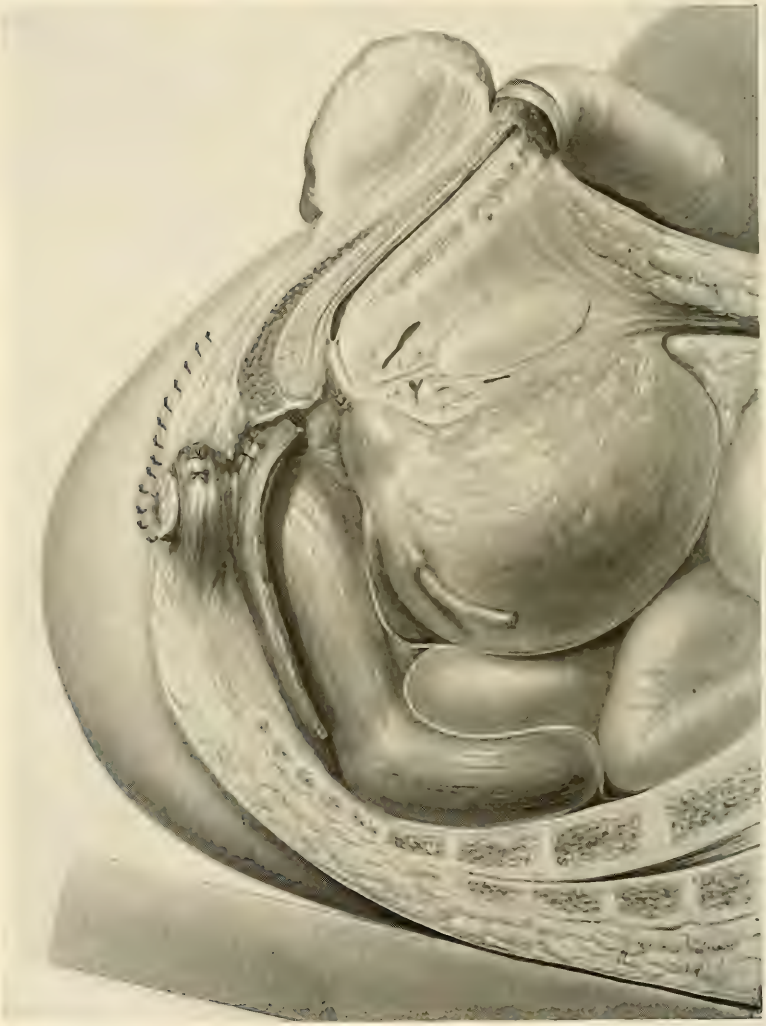

Fig. 459.—Showing the Various Layers of Sutures: Urethral, Prostatic, Sphincter Ani, and Mucocutaneous Sutures.

A study of the literature shows that in 1889 Ziembecki[16] was the first author who had used the rectal technic somewhat approaching our method. He too loosened the rectum from its lower attachments, but instead of removing the fistula bearing the lower cuff of the bowel he simply sutured the openings into the ruethra and rectum and then rotated the rectum to one side so as to bring the two orifices out of line

with each other. Paul Segond[17] applied the principle of pulling down the rectum in attacking rectovaginal fistulæ, and in 1903 Tedenat[18] reported having successfully operated on 2 cases by dilating the anus, dissecting up the cuff of rectal mucosa, closing the urethral orifice thus exposed, and then pulling the rectal mucosa down so that the rectal orifice of the fistula is brought to the anterior margin. Wildbolz has

FIG. 460.—SHOWING LONG URETHRAL PROSTATIC TRACTOR INTRODUCED INTO BLADDER, OPENED OUT, AND TRACTION MADE, TO DRAW DOWN PROSTATE AND FACILITATE SEPARATION OF RECTUM ABOVE POINT OF FISTULA.

also published a similar technic. Elting[19] has adopted an analogous attack upon ordinary fistula *in ano*.

We were not acquainted with the paper of Tedenat until after 3 of our cases had been operated on. While he was the first to apply the Whitehead principle to the cure of recto-urethral fistulæ, he did not dissect around the whole circumference of the anus and rectum, which

is most important to do. In our experience it is most important to supply suprapubic drainage and secure absolute rest for the urethral suture in order to prevent breaking down of the perineal wound and recurrence of the fistula. This condition, which had heretofore been considered one of the great bugbears of surgery and extremely difficult to cure, has been rendered entirely amenable to radical surgery even where several previous unsuccessful operations have done much damage and filled the perineum with extensive scar tissue. By this operation it has been possible also to cure not only incontinence of feces but also by plastic procedure upon the prostatic orifice and external sphincter to cure also incontinence of urine. [More recently I have employed my long prostatic tractor, through the penis, to draw down the prostate and bladder and facilitate the separation of rectum above the fistula] (Fig. 460).

Cancer of the Prostate.—In Keen's Surgery, Volume VI, 1912, I collected carefully the literature and added a study of cases upon which radical operation had been performed at our clinic. Since then I have prepared for the Seventeenth International Congress of Medicine in London a paper on the Diagnosis and Treatment of Early Malignant Diseases of the Prostate from which the following paragraphs are taken:

In order to arrive at an idea of the symptoms and findings on which an early diagnosis of cancer of the prostate can be based I have carefully collected all of the cases of cancer of the prostate which might be considered as being early cases when admitted. I find among my records 12 such cases, which may be divided into three classes, viz.:

I. Those in which the only pathologic process present is cancer—6 cases.

II. Those in which cancer is associated with hypertrophy on benign adenoma—5 cases.

III. A case of chronic prostatitis with small area of cancer in it.

From a study of these early cases (and other later cases) it appears that the symptomatology of cancer of the prostate in the early stages is almost identical with that of benign hypertrophy, so that we must look entirely to a careful physical examination to furnish suspicion of cancer. There was nothing in the appearance of any of these 12 patients to suggest malignant disease; they were not emaciated, nor were they suffering pain, with the exception of 4 cases, and in these it was not severe. The urine was free from blood in all cases. In the 6 cases not associated with hypertrophy the size of the prostate was described as considerably enlarged in 3 cases, moderately enlarged in 2 cases, slightly enlarged in 1 case. The surface was smooth in 2 cases, rough in 3 cases, nodular in 3 cases. Here we have in 6 cases conditions which should always make one suspicious of cancer; for the benign adenomatous prostates, unless associated with considerable inflammation or with calculi of the prostate, are nearly always smooth, though they may be lobulated. The consistence was described as very hard in all of the 6 cases not associated with hypertrophy, and in some was said to be "stony hard." In 5 cases both lobes were involved, but in one case

the left half of the prostate was normal. In this interesting case (in which urgency of urination had been present one year) the right lobe was enlarged, very hard and rough, the induration extending to the median line, where it ended abruptly, forming a straight edge well elevated above the normal left half of the prostate. The lower portion of the right seminal vesicle was involved, as was the posterior part of the membranous urethra. The contrast between the two halves of the prostate here was most sharply defined. In one case there was a hard nodule in each lobe, which was otherwise soft on each side. Two years later the whole prostate was rough, irregular, very hard, and greatly enlarged. In the other 4 cases, although in 2 symptoms had been present only one year, the prostate was completely invaded by cancer on both sides, although the vesicles were mostly free.

A review of the 5 cases in which both cancer and hypertrophy were present shows that the presence of hypertrophy of the lateral lobes generally gives an elasticity to the prostate on deep pressure which is very deceptive. In these cases a small layer or nodule of cancer lying between the capsule and a hypertrophied lobe may be compressible on deep pressure. More delicate palpation, and particularly palpation upon a cystoscope in the urethra, will often show the real induration of the local carcinomatous area. These localized areas of stony induration or nodulation should always be suspected and subjected to early perineal exploration.

The vesical mucosa was normal in all of these cases, and no invasion of the trigone was present as shown by the cystoscope and at operation.

The 7 cancer cases in which no coexistent hypertrophy of the prostate was present showed, on cystoscopic examination, only a small median bar, with no intravesical enlargement of the lateral lobes. In one case the median portion formed a small sessile lobe, and one case showed both a median bar and a slight right lateral enlargement.

The characteristic picture, then, in early cancer of the prostate is a small bar, unaccompanied by marked lateral intravesical enlargement.

In one case a carcinomatous constriction of the prostatic urethra was present, requiring dilatation before cystoscopy was possible, but there was no evidence of ulceration of the urethra in any case. In later cases stricture of the prostatic urethra is not an uncommon finding, and is to be considered very suggestive of cancer.

The **diagnosis** of early carcinoma of the prostate is principally based on the finding of great induration in a portion of the prostate, as shown by our cases. It may occur as one or more small nodules or lobules which may be prominent or embedded in the prostatic tissue, but apparently always palpable per rectum In later cases one whole lobe or both lobes may be involved, but the disease apparently remains well within the prostatic capsule for a fairly long period, and the line of progress is upward, beneath the fascia of Denonvillier, the ejaculatory ducts and the structures between the lower ends of the vasa deferentia, the bladder being invaded from behind after the cancer cells pass beyond the limits of the prostate. Induration beneath the prostatic urethra

and immediately above the prostate and easily palpable with a finger in the rectum and a cystoscope in the urethra as a hard subtrigonal thickening is of great diagnostic value. In later cases this "intervesicular plateau" of induration becomes more and more pronounced, but it is remarkable how long the upper portions of the seminal vesicles and vesical mucosa are free from invasion.

It is only by being continually suspicious of marked induration, even if confined to a small nodule, that early diagnosis can be expected and radical cures obtained.

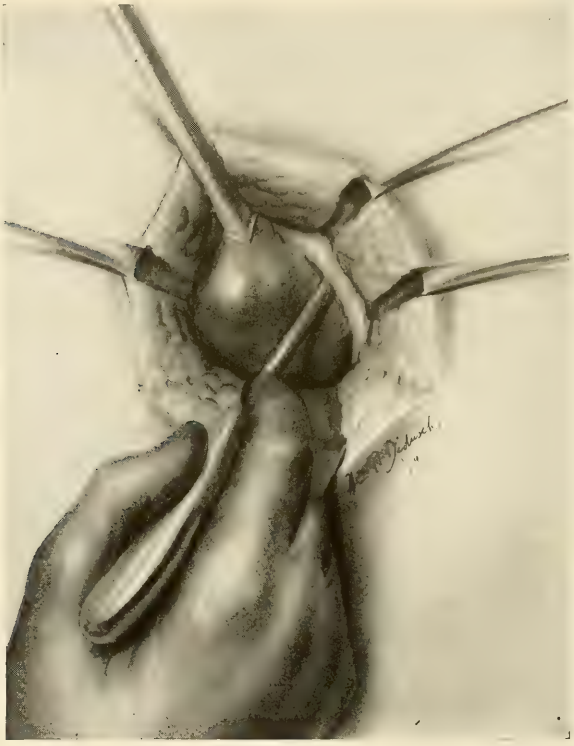

Fig. 461.—Separation of Lateral Fascia from the Prostate.

The Radical Cure.—In October, 1905 I published in the Johns Hopkins Hospital Bulletin an operation for the radical cure of cancer of the prostate. Since then further details and cases have been furnished in other articles.

In the first communication on the subject a thorough study of the literature was presented which showed that whereas various operations had been employed in cancer of the prostate, no systematic radical procedure, coupled with plastic repair of the defect produced, had ever been recommended.

The plan and scope of the operation was based on pathologic studies which showed that if a radical cure was to be expected the seminal

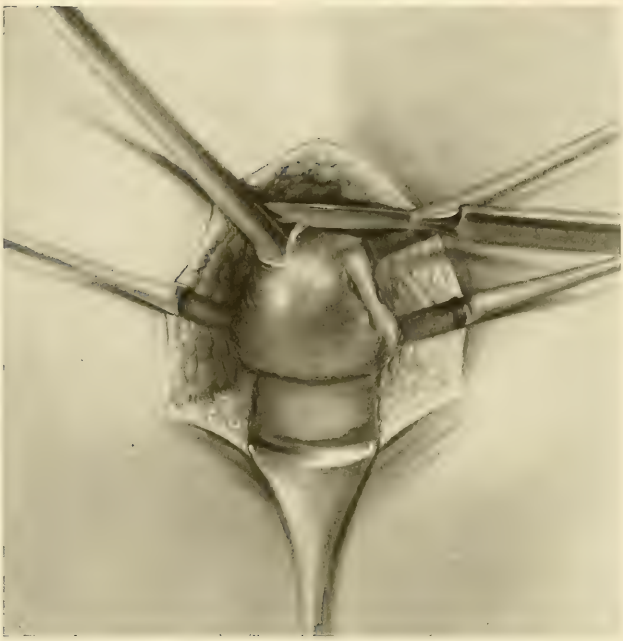

FIG. 462.—DIVISION OF MEMBRANOUS URETHRA.

FIG. 463.—EXPOSURE OF SEMINAL VESICLES AND LIGATION OF VASA DEFERENTIA.

vesicles and most of the trigone, with the intervening tissues, would have to be excised in one piece with the whole prostate (capsule, urethra, internal sphincter, cuff of bladder, and part of membranous urethra).

The radical operation which was described at length in Vol. IV and again in Vol. VI of Keen's Surgery has been remarkably successful in obtaining cures, although many of the cases could not be called favorable. It was shown that strictures did not occur after operation, and

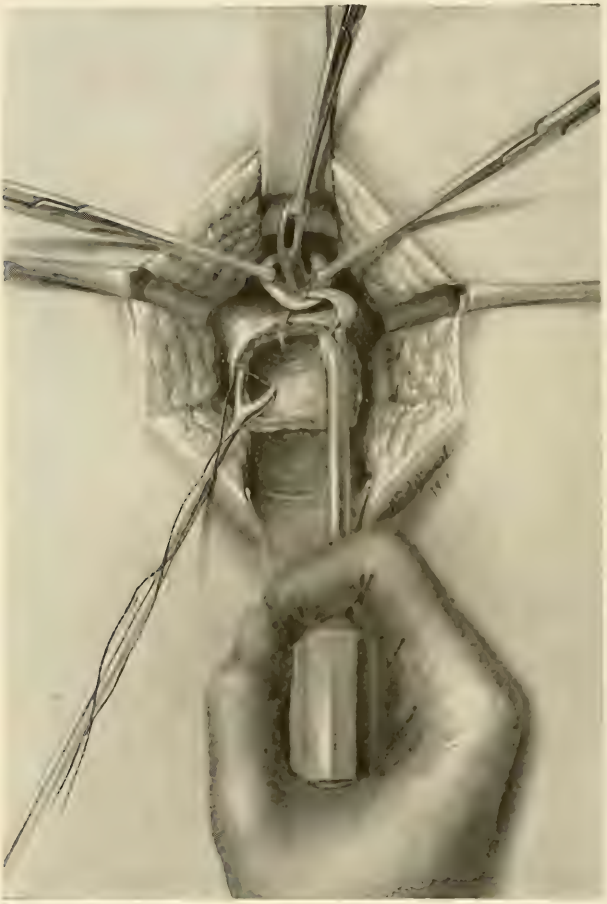

Fig. 464.—Use of "Boomerang" Needle-holder in Making Anastomosis Between Bladder and Membranous Urethra.

the general condition of the patient was excellent with the exception of one drawback, viz., incontinence of urine, which in some cases was present both night and day, and in others only by day. As the triangular ligament and external sphincter had been preserved intact studies were made to determine why this was not sufficient to give good urinary control, and the conclusion was reached that it was due to the fact that in radically removing the prostate with its capsule, urethra, cuff of the bladder and seminal vesicles, the nerves and vessels of the

periprostatic space which go to supply the external sphincter and region of the triangular ligament were divided or injured, thus producing paralysis of the external sphincter. Investigation showed that that portion of the pelvic fascia which passes in front of the prostate is closely applied to the lateral and anterior surfaces of the prostate and separates the periprostatic vessles and nerves from the prostate itself, and that it is not difficult to separate or lift up this fascia from the prostate and do a radical operation while still preserving the important vessels and nerves above referred to. Accordingly, the radical procedure was modified slightly to carry this out. After exposing the prostate through the perineum by the technic previously described, and introducing the prostatic tractor through the usual urethrotomy wound, inspection

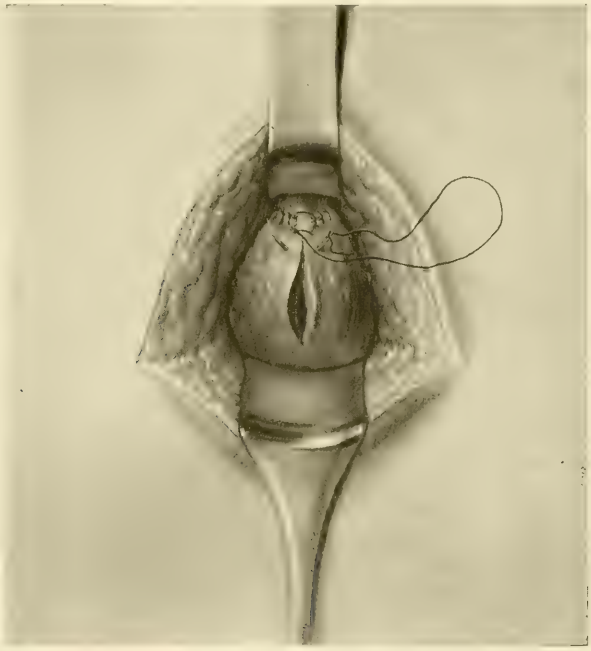

FIG. 465.—FINAL CLOSURE.

of the lateral surfaces of the prostate was made, and by means of blunt and occasional sharp dissection the fascia was lifted from the anterior surface of the prostate, division of the urethra in front of the tractor considerably facilitating this procedure, as shown in Figs. 461 and 462. By this means it is easy to separate the prostate from its lateral and anterior attachments with practically no hemorrhage, and carry this blunt dissection backward until the bladder is reached at the prostatovesical juncture where the knife is plunged into the bladder and the incision continued on each side with knife or scissors, hugging the prostatic edge, and finally dividing the trigone transversely at a point 1 cm. below the ureteral orifices, as shown in Fig. 463. The subsequent steps of the operation in which the vasa deferentia are isolated, picked up,

clamped and divided, and the seminal vesicles freed, their deep attachments clamped, divided and ligated, and the whole prostate with its capsule, cuff of bladder, seminal vesicles, and vasa deferentia for 5 or 6 cm. in length removed in one piece, is shown in Fig. 463. The final closure and situation after operation is indicated in Figs. 464–466. By means of this technic not only has it been possible to avoid much hemorrhage, which previously occurred from division and

Fig. 466.—Longitudinal Section Showing Result of Suture of Bladder to Urethra.

injury of vessels in the prevesical space, but results obtained now in 4 cases show that complete urinary control has been conserved. Some of these patients, now operated upon five years ago, are able to retain urine all night and void at normal intervals during the daytime. In no case has stricture of the urethra developed or sounding been necessary. The functional results are apparently just as satisfactory as after the ordinary conservative prostatectomy for benign hypertrophy.

Thus the objection to the operation which has been seriously urged by Judd and others (with which I did not agree, as I have always felt that a radical cure, even with incontinence, was preferable to a lingering death from cancer) has been removed.

The Use of Radium in Cancer of the Prostate.—In 1913 Pasteau and DeGrais reported a few cases of cancer of the prostate and bladder in which truly striking results had been obtained by the use of radium introduced into the urethra through an ordinary catheter. This led me in 1914 to procure 100 mg. radium and to try it in certain selected cases. It soon became evident that for accurate work much more exact methods and special instruments would be necessary, and in the machine-shop of the Brady Institute I set about to design and construct instruments to meet the varying needs in vesical and prostatic cancer.

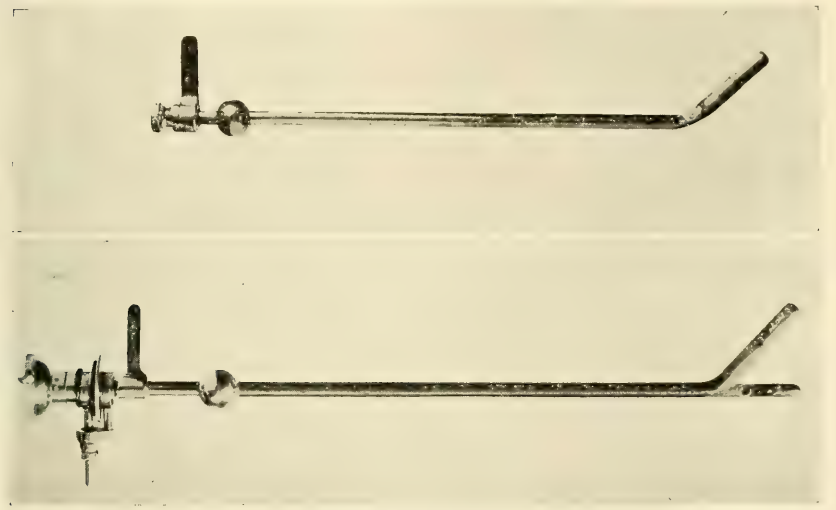

FIG. 467.—RADIUM INSTRUMENT WITH HOLLOW SHAFT FOR APPLICATINGS INTO THE BLADDER UNDER CYSTOSCOPIC INSPECTION.

A, Instrument ready for introduction into the bladder; *B*, instrument with cystoscope introduced.

The accompanying illustrations show the different models so well that little description is necessary. The small straight cystoscope which is used in my cystoscopic rongeur was used as a basis around which to construct the various radium instruments.

Radium instrument 1 (Fig. 470) carries the radium in its beak. The slender glass tube containing the radium is enclosed in a platinum capsule which slips easily into the open tubular end of the beak of the instrument and is held there by friction. The instrument is passed through the urethra with an obturator, which is then withdrawn, the bladder washed out, and the cystoscope introduced, making it possible to locate the region to be treated and to apply the capsule containing radium directly to it (Fig. 468). When in the proper position the instrument is held fixed by the mechanical hand attached to the cystoscopic table shown in operation in Fig. 469. This instrument

and the accurate methods of use were demonstrated to several medical societies in 1915.

Radium instrument 1 has proved satisfactory for application to the neck of the prostate, bladder, trigone, and certain portions of the lateral

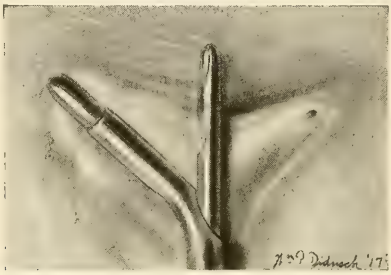

Fig. 468.—Showing Instrument (No. 1) Used in Placing the Radium Upon the Trigone which Has Been Invaded by Carcinoma of the Seminal Vesicle.

and posterior walls. It is usually easy to see satisfactorily with the cystoscope and to place the radium directly on the lesion to be treated.

For intra-urethral treatments of the prostate it is not necessary to have an instrument carrying a cystoscope, and on this account a simpler applicator was designed (Fig. 470). With this instrument it is easy to

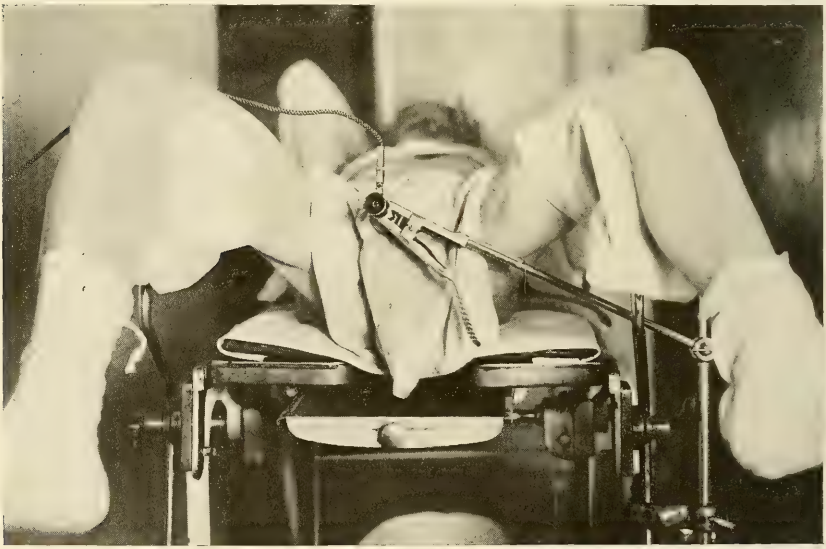

Fig. 469.—Illustration Showing the Method of Giving Urethral and Bladder Radiations. The mechanical arm attached to the table holds the instrument in desired position.

place the tube of radium at the beginning, middle, or deepest portion of the prostatic urethra without overlapping, and to hold it in place by means of a special clamp attachment to the operating table on which the patient lies. The position of the radium can be verified, if desired, by means of a finger in the rectum. Applications of radium can also

be made through the rectum to carcinomata of the prostate and seminal vesicles. For this purpose the same instrument is employed, the tube containing the radium placed in position, under direction of the finger in the rectum, and held in place by means of a clamp held to the table, as shown in Fig. 471. Charts are used showing the exact location to

Fig. 470.—Radium Instrument No. 1, with Solid Shaft for Urethral and Rectal Applications.

which the radium is applied, and the duration or milligram hours are affixed with the date. In this way it is easy to avoid applying the radium again in the same position until several weeks have elapsed, and thus radium burns of the rectal mucosa are prevented. Figure 472 shows a chart in which numerous applications of radium were made to a case of carcinoma of the prostate and seminal vesicles through the rectum,

Fig. 471.—Showing Method of Giving Rectal Radiations.

urethra, and bladder (Fig. 473) without producing burns and with excellent clinical results.

Where the carcinomatous invasion of the seminal vesicles extends far laterally it is sometimes difficult to reach it with instrument No. 1 (Fig. 470), and on this account instrument No. 2 (Fig. 474), by means of which the radium is carried in a parallel direction with the shaft of

the instrument to a distance of 3 cm., can be employed. In other locations these instruments may be used to apply the radium in different directions around the prostatic orifice or adjacent walls of the bladder. By thus changing the position and direction of the tube of

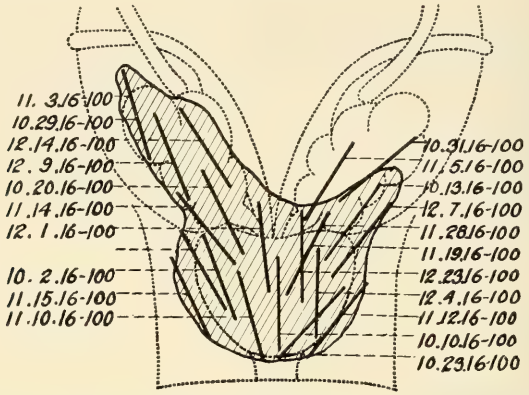

Fig. 472.—A Case of Cancer of the Prostate and Left Seminal Vesicle (Right Vesicle Slightly Involved).

The radium treatments, each representing 100 milligram hours, are shown and date of each is recorded.

radium overlapping is avoided and burns excluded. Important papers on the use of radium in cancer of the prostate have been published by Barringer.

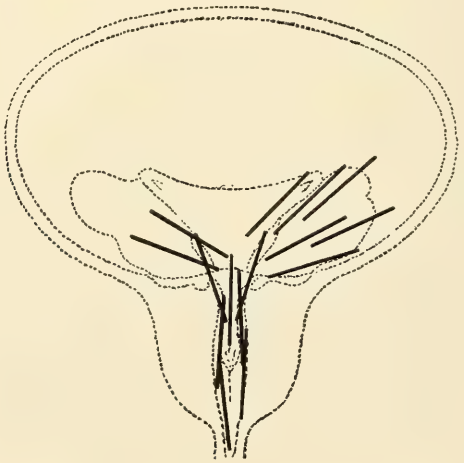

Fig. 473.—Chart Showing the Transvesical and Transurethral Treatments Given in Case Illustrated in Fig. 472. Each Line Equals 100 Mg. Hrs.

A study of 66 cases of cancer of the prostate and seminal vesicles treated with radium was reported by Young and Frontz[20] in 1917. In 42 of these the tumor was extensive, not only the prostate but the seminal vesicles being involved. In 19 the process was confined apparently

to one-half of the prostate and the corresponding vesicle, while in 4 the vesicles were apparently free from invasion.

The diagnosis of carcinoma was made by rectal examination alone in all but 4 cases. These had previously been operated upon, the tissue removed showing typical carcinoma. The diagnosis of malignancy was confirmed in 12 other cases, 9 of which were subsequently operated upon and 3 coming to autopsy. In the remaining cases in which histologic confirmation was impossible, the findings were typical of malignancy.

The results from radium treatment of carcinoma of the prostate and seminal vesicles have been most encouraging in many cases. Cases presenting marked urinary obstruction have responded in the course of six weeks to two months, and in some instances a large residual urine has diminished to zero. Cases giving a history of voiding from ten

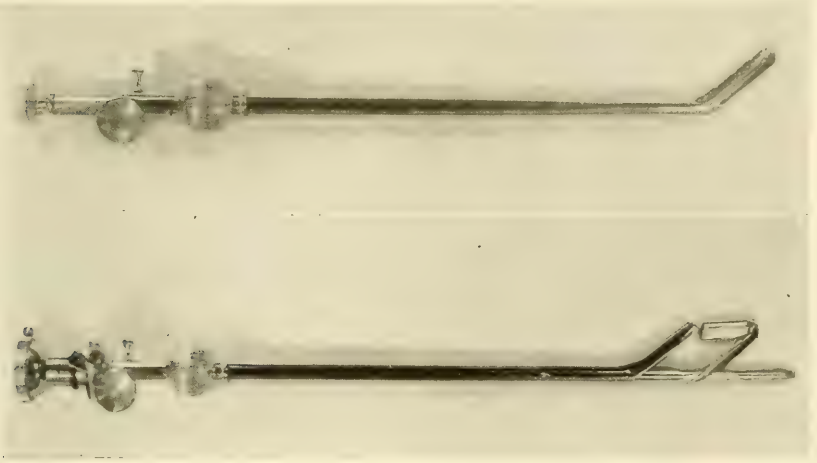

FIG. 474.—INSTRUMENT NO. 2, CLOSED AND OPEN.
This carrier is of value for radiating cancer of the seminal vesicle through the bladder when the carcinomatous invasion extends far lateralward.

to twelve times at night and then only with extreme difficulty and pain, have shown, after a course of treatment, marvelous improvement, urination being accomplished in a normal manner. In our series of 66 cases, 19 received less than 1200 mgm. hours, while the remaining 47 were given more than this amount, the radiation in many cases ranging from 3000 to 5000 mgm. hours. We have analyzed our results as follows:

Cases with Complete Retention.—In 11 cases retention of urine was complete. In 2 cases the treatment was less than 1200 mgm. hours, while in the remainder it averaged about 3000 mgm. hours. The obstruction in these cases, with one exception, showed no improvement, 8 of them subsequently coming to operation for the relief of urinary retention. The single case was only partially benefited and has had to resort to catheter at night since.

Frequency and Pain.—Fifty-one cases give a history of more or less frequency and dysuria. In 17 the radiation was less than 1200 mgm.

hours and the improvement symptomatically very slight. In the remaining cases receiving adequate treatment the improvement in many was very striking, 9 being almost completely relieved of obstructive symptoms, 9 showing marked improvement, 9 responding only slightly, 7 being unchanged.

Size and Consistence.—Those cases which have responded symptomatically have shown also, as a rule, improvement in the size and consistence of the prostate and seminal vesicles. In some instances the prostate has changed from a stony consistence to the normal elasticity. The size has also diminished, although in this respect the change has not been so striking. In many of these cases examination after treatment would lead to a diagnosis of adenomatous hypertrophy. The change in size and consistence of the seminal vesicles has not been ask great as the improvement noted in the prostate. Figures 475 and 476

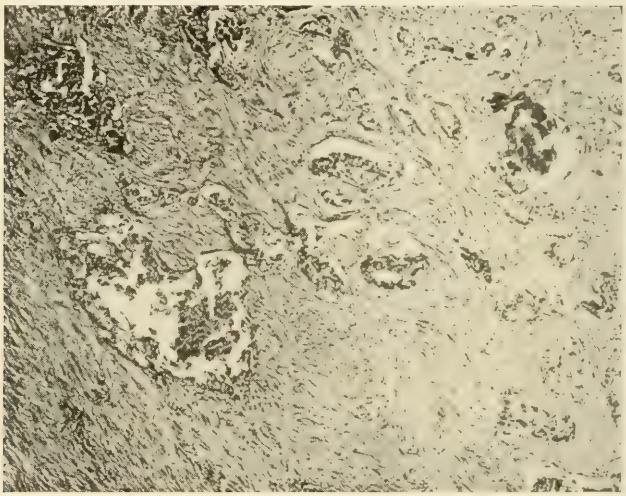

Fig. 475.—Low-power View of Section of Prostate Showing Degenerative Changes After Radiation.

show the effect of radium upon cancer cells in a case subsequently subjected to prostatectomy.

The following cases are cited as illustrative not only of marked symptomatic improvement but also of reduction in size and consistence of the prostate and seminal vesicles.

No. 5446, aged eighty. Admitted October 12, 1916, complaining of frequent and difficult urination. For two years prior to his coming to the hospital he had had increasing frequency, and for six months urination was accomplished with great difficulty and pain. Rectal examination on admission revealed a very definite carcinoma involving the entire prostate and left seminal vesicle. On cystoscopy 325 c.c. of residual urine were recovered. Study of the prostatic orifice showed some median enlargement and considerable trabeculation of the bladder wall. From October 12 to December 16, 1916 500 mgm. hours of radium were given per urethram and 1500 per rectum. Examination

at the end of this series of treatments showed marked improvement in the induration, although the condition was still suggestive of carcinoma. Treatment was resumed January 8, 1917, and during the next three weeks 500 mgm. hours were given per urethram and 200 per rectum. At the present time (April 25, 1917) urination is accomplished with ease and the patient voids at normal intervals. There is no residual urine. Rectal examination reveals a prostate of normal size, smooth, and slightly indurated. Both seminal vesicles are slightly thickened and adherent. The case now presents a picture of slight prostatitis and seminal vesiculitis.

No. 5193, aged sixty-two. Admitted June 11, 1916, with a history of urinary frequency beginning three years before. These symptoms gradually became more marked, and for the past year he has been required to pass his urine at hourly intervals during the day and from two

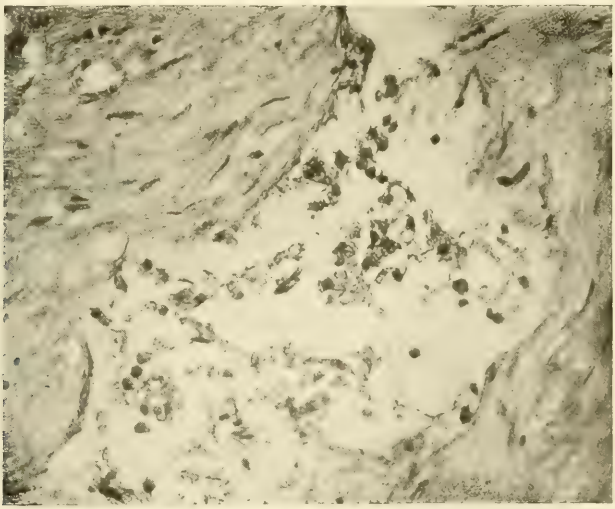

FIG. 476.—HIGH-POWER VIEW OF SECTION OF PROSTATE SHOWING EXTENSIVE DESTRUCTION OF CANCER AREA.

to four times at night. Throughout the course of his illness there had been considerable hesitancy and dribbling, and during the year before admission urination had been accomplished only after considerable straining.

Rectal examination showed that the prostate and seminal vesicles were involved. The prostate, although not much larger than normal, was very irregular, fixed, and markedly indurated, particularly the left lobe. The induration was continuous, with a mass in the region of both seminal vesicles, both of which were enlarged, nodular, fixed, and very hard.

The patient received two courses of treatment, the first being carried out between June 12, 1916 and July 20, 1916, during which time 1400 mgm. hours of radium were given per rectum and 400 mgm. hours per urethram. At the end of this series the prostate and seminal

vesicles showed very little change and the symptoms only slight improvement. The treatment was resumed in September, 1916, and from September 16th to October 14, 1916 1000 mgm. hours were given per rectum and 300 per urethram. The prostate was of normal size and everywhere elastic. Both seminal vesicles, although moderately prominent, were only slightly indurated. Rectal examination of the prostate and seminal vesicles if made now for the first time would suggest the diagnosis of prostatitis and seminal vesiculitis, and not cancer. Since the last treatment in October, 1916, there has been gradual improvement. Urination is now (March, 1917) accomplished with ease, the patient holding his urine for three hours during the day and voiding twice at night.

No. 4726, aged seventy-three. Admitted November 18, 1915, with a history of slight urinary frequency beginning one year previously. Shortly after the onset urination became quite difficult. These symptoms gradually increased and for several months before admission the patient had been voiding every few minutes day and night. Finally complete retention requiring catheterization came on.

Rectal examination showed the prostate somewhat enlarged, its surface irregular and both lobes markedly indurated, the consistence of the left lobe being stony and undoubtedly cancerous. Both seminal vesicles were enlarged and indurated, the left apparently malignant, the right inflammatory. Cystoscopy: Residual urine 100 c.c. Bladder capacity 150 c.c. Both lateral lobes only slightly enlarged intravesically; moderate trabeculation of bladder wall and hypertrophy of trigone. Nothing suggesting carcinomatous invasion of bladder.

During the first month of treatment the patient received 500 mgm. hours to the urethra and bladder and one external radiation of 200 mgm. hours to the perineum—time nine hours, distance 3 inches. Treatment was resumed nine weeks later, and during the next seven weeks 950 mgm. hours were given per rectum and 825 per urethram. Frequent rectal examinations have shown gradual improvement in the condition, and at the last examination (April 6, 1916) the prostate was not enlarged. The right lobe was somewhat irregular, but perfectly elastic, while the left was smooth and still considerably indurated, but much less so than on admission. There has been no urinary difficulty since the treatment one year ago (letter February, 1917), and the patient is practically free from symptoms. Urination is perfectly normal and patient is able to hold urine for five hours.

The use of radium in the treatment of carcinoma of the prostate and seminal vesicles in many cases has resulted not only in marked symptomatic improvement but also in definite reduction in the size and consistence of the tumor. In several of the treated cases subsequently coming to operation it has been possible to secure prostatic tissue for microscopic study. Some of the adequately treated tumors (those obtaining from 4000 mgm. hours) show extensive destruction of the cancer cells throughout large areas. In other areas the general architecture of the tumor is altered and the cells and nuclei appear in

varying stages of degeneration. The histologic change in several of these tumors is most encouraging, and it seems certain that radium treatment may have a distinctly curative effect in some of them.

The internal use of radium, either by urethra of bladder or by rectum, by accurate methods of control and fixation, would seem to be productive of far better results than the employment of much larger amounts externally, the chief difficulty of the latter method being the greater distance between the portal of application and the tumor.

The irritating effect of radium, which was formerly the great objection to its use in the urethra and rectum, has been avoided by the accurate methods of use which I have introduced, and if the dose is carefully regulated and if care is used to avoid too frequent application to any one spot. The discontinuance of treatment at the first sign of rectal irritation cannot be too strongly emphasized, for if the treatment be carried beyond this point serious burns may result. Frequent rectal examinations may reveal a thickened rectal mucosa which may be the first evidence of irritation. With the onset of rectal irritation urethral and vesical radiation may be substituted. The urethral and vesical mucosa is apparently quite resistant to the action of radium, and in our series no ill-effects have been noted following intensive treatment from these points. In these cases, however, it is well to mention that we have always employed a screen of 1 mm. of platinum.

The determination of a safe interval between the disappearance of rectal symptoms and the resumption of treatment will vary with the individual case, the severity of the symptoms, their duration, the amount of radiation producing the original irritation, and the character of the rectal mucosa. Cases having had rather severe and prolonged symptoms should be held for two or three months before rectal treatment is resumed. Where large amounts of radiation have been tolerated, finally resulting in more or less irritation, the interval between the disappearance of symptoms and the resumption of treatment should be much longer than in those cases showing evidence of irritation after a few hundred milligram hours.

William Duane,[21] of Harvard, and later Barringer, of New York, and others have inserted radium element and the emanations of radium in the treatment of most of their cases of carcinoma of the prostate and seminal vesicles. The technic of application they have usually employed is as follows: The emanations are placed in the tip of a gold or steel needle from 4 to 6 inches in length, which is inserted through the perineum into the carcinomatous prostate or seminal vesicle, as has also been done by Duane and others in the treatment of carcinoma elsewhere. The introduction of the needle is made after preliminary injection of $\frac{1}{2}$ per cent. novocain and is practically painless; 50 millicuries of emanation have usually been employed, and this is allowed to remain in one lobe of the prostate for six hours, when, if desirable, it is transferred to the other lobe. The needle is introduced under the guidance of a finger in the rectum which insures accurate application of the emanations to the point desired. The treatment is followed

usually by pain in the prostate and urinary frequency, which comes on about three days after the irradiation and lasts for a number of days to several weeks. In nearly all of his cases the treatment has been given but once in two or three months, and in no case has it been repeated until all symptoms of irritation have disappeared.

In Barringer's experience very few of the advanced cases, in which there was extensive involvement of the prostate and seminal vesicles, have shown any improvement following irradiation. In cases reacting more favorably to the treatment, however, there has been a marked reduction in the size or even a disappearance of the carcinoma, and histologic examination of specimens obtained subsequently at operation has shown atrophy and fibrosis.

Following the method of irradiation outlined above Barringer has noted little or no improvement in urinary obstruction, and in no case has the amount of residual urine diminished appreciably. He has found, however, that while there has been no improvement in this respect, there has been no apparent increase in the obstruction during treatment. The inadequacy of this method of application for cases having urinary obstruction has led Barringer recently to modify his technic for this type of case. He conceived the idea of introducing with the cysto-urethroscope capillary tubes containing 2 to 4 millicuries of emanation into the suburethral portion of the prostate and allowing them to remain. This has been carried out by means of a cysto-urethroscope and flexible needle, as shown in the accompanying illustration. There is apparently very little reaction following this method of application, and in several cases in which it has been employed the results have been very encouraging.

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CHAPTER XLIX

SURGERY OF THE EXTERNAL MALE GENITALS*

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WAR WOUNDS OF THE EXTERNAL MALE GENITALS

Wounds of the external male genitals are practically always associated with wounds of the abdomen, buttocks, or thighs, which latter are of greater importance than the genital injury. The principles of war surgery of the male genitals may be summarized as follows:

The Urethra.—Wounds of the penile urethra, generally speaking, bleed freely for only a brief time, and do not result in retention of urine. Therefore no immediate treatment is required.

Injury to the scrotal or perineal urethra usually results either in retention of urine or in urinary extravasation into the scrotal or perineal tissues. Immediate relief is therefore required, and this is to be supplied by suprapubic drainage of the bladder which leaves the original wound dry and under the best possible conditions for repair. In performing the usual wound toilet the urethra may be treated very conservatively on account of the great vascularity of the spongy tissue.

Plastic operations upon the urethra have been performed with extraordinary success by Rochet, Cathelin, and others. The operation should not be attempted until all active suppuration has ceased. Then the ends of the urethra are brought together after they have been denuded of granulations and scar tissues. Suprapubic drainage is almost an essential to success of the operation.

If there is considerable loss of substance of the urethra in its perineal or scrotal portion the two ends of the urethra should be fistulized, *i. e.*, sutured to the overlying skin. Six or eight weeks later the two fistulæ are cut free with their bridge of skin between and sunk deep in the tissues of the perineum which are brought together over them, but the skin is not sutured. The bladder is drained suprapubically until the perineal wound has healed.

Loss of substance of the pendulous urethra is more difficult to supply. The saphenous vein has been transplanted once or twice with success, the mucous membrane of the vagina has been borrowed for the purpose, and the various operations for hyperspadias have been modified to suit the fistula.

Penis.—War wounds of the penis may be treated even more conservatively than are those of the urethra, with the exception that hemorrhage may require early suture of the glans or the corpora cavernosa. But every effort should be made to disturb the tissues as little as pos-

* Supplementary to Chapter LX, Vol. IV, p. 473.

sible until granulation has taken place. Rochet, for example, was able to save a glans penis that was removed several centimeters from the rest of the organ and attached only by a piece of foreskin.

Scrotum and Testicle.—Wounds of the scrotum call for wide and immediate drainage after the usual removal of necrotic tissue. Wounds of the testicle, on the contrary, should be treated with the greatest conservativeness. If the blood-supply is entirely destroyed the organ must, of course, be removed; otherwise it should be left untouched or a few stitches taken in the albuginea. As the wound heals the testicle will often protrude more and more, covered with a thick mass of granulations. The removal of this together with the underlying scar permits the remains of the scrotal skin to be drawn over the ectopic testicle. Even if the scrotum is almost completely shot away, it will reconstruct itself, the extraordinary ability of the scrotal skin to stretch to cover in the testicles having been noted a generation ago.

THE TREATMENT OF MALIGNANT NEOPLASMS OF THE EXTERNAL GENITALS

There are but two types of malignant neoplasm of the external male genitals which occur in this country with sufficient frequency to have received extensive study of late years. These are the epithelial carcinoma of the penis and the malignant teratoma of the testicles.

Malignant neoplasms of the urethra and of the scrotum are recorded, but are rare in this country. I have seen 4 of the former and 2 of the latter.

These neoplasms have already been described (Keen, Vol. IV, pp. 484–487, 521, 600). Some of the salient features determining the efficacy of treatment of these neoplasms will, however, be repeated in the following paragraph.

Epithelial Carcinoma of the Penis.—The growth begins as a wart or an ulcer on the glans penis, or on the prepuce. It is usually an acanthoma. Phimosis is distinctly a predisposing cause. The patients with this disease whom I have seen have all had long foreskins and, with one exception, tight ones. The filth that accummulates beneath a foreskin that has never been retracted is an obvious cause of epithelioma.

The tumor at first is painless, and may not bleed. Occurring beneath the foreskin of a middle-aged man it may attain extraordinary proportions before it attracts his attention. One patient came to me complaining only of urethral stricture. I placed him in the hospital and did a complete extirpation of the penis, only to find a metastasis at the point of implantation of one of the corpora cavernosa in the pubic ramus. This is a characteristic route of invasion. The neoplasm ulcerates deeply into the glans penis, and thence invades one or both corpora cavernosa directly. Once it has reached these, it spreads throughout them in small nodules of carcinoma.

The groin lymphatics are invaded by absorption from the preputial cavity. Absorption occurring along the corpora cavernosa or the corpus spongeosum leads to the pelvic and lumbar glands.

Thus, epithelioma of the penis is often a concealed rather than an open neoplasm, and is, accordingly, neglected until secondary metastasis has made it incurable.

If seen early it may be cured as in epithelioma of the lip by radiation, whether from radium or the *x*-rays. I have removed a small nodule on the foreskin by circumcision. The patient remaind well for a year and died of pneumonia. For more advanced cases it is wise to operate very radically. The fact that the tumor is apparently confined to the glans penis does not exclude the possibility of a metastasis deep down in one or other of the corpora cavernosa. I therefore prefer extirpation of the penis to any other form of amputation. The inguinal glands should be removed in one piece with the penis, and the extirpation followed by radiation to prevent recurrence.

Malignant Teratoma of the Testicles.—Though the neoplasm is of congenital origin, the patient usually pays no attention to it until in his early adolescence it begins to take on malignant changes. The tumor grows very rapidly, extending up the lymphatics of the cord and along its nerve trunks (Hinman), often causing a neoplastic phlebitis of the cord. Death frequently results within a year of the time the tumor was first noticed.

Hinman records a mortality of at least 87 per cent. among 24 cases operated upon by simple castration, and urges more radical operative measures.

Two classes of cases may be distinguished:

1. The *inoperable*, in whom secondary metastases are discovered before operation. These should have the benefit of removal of the original growth together with all the structures of the spermatic cord up to the internal abdominal ring, and even beyond this, if there seems any prospect of getting beyond the immediate extension of the disease. Large abdominal metastases in the lumbar glands obviously defy surgery. But the effect of radium in controlling these growths is truly extraordinary. The result of efficient radiation is that the visible and palpable tumor masses usually fade away within a week or two of a single massive treatment.

This treatment has not been employed for a sufficient number of years or on a sufficient number of cases to permit any prophecy as to its ultimate results. Relapses have occurred at the end of a year, but at least the method is an excellent palliative one for the treatment of cases for whom nothing else can be done.

2. The second class of cases, the *operable*, are those without palpable metastasis. These should be subjected to the radical operation as originally performed by Cuneo (referred to by Hinman).

The operation is performed as follows:

1. The spermatic cord is freed up to the internal abdominal ring and there divided upon a clamp with the actual cautery. The testicle is then removed and divided to be sure that it contains a teratoma.

2. If teratoma is found, the patient's side is elevated by pads placed along the back and under the opposite loin. The opposite leg is also

slightly flexed, the position being a bent "dorsolateral" one, but facing upward, not downward, as in the kidney position.

3. The incision is then carried from the point at which the spermatic cord has been divided to a point about 2 cm. inside of the anterior superior spine of the ilium, in a direction parallel to Poupart's ligament. It is then curved backward to a point about 1 cm. below the tip of the twelfth rib. This curve is chosen in the expectation of placing the deeper incision below the iliohypogastric nerve.

4. The external oblique is divided in the course of its fibers, the deeper muscles in the line of incision. The hypogastric branch of the iliohypogastric nerve will usually be seen and should be spared, though the iliac branch must be sacrificed.

5. The peritoneum is then elevated from the parietes sufficiently to expose the iliac vessels, the aorta and vena cava, and the renal vessels.

During this dissection the spermatic vessels tend to adhere to the peritoneum, but this can be prevented by beginning the dissection from below upward and pulling gently on the veins as the peritoneum lifts. They will then remain on the parietes.

6. The lymphatic areas lie between the spermatic veins externally and the iliac and the great abdominal vessels internally, and also run upward to the renal pedicles. Dissection of this area is begun from without inward and from below upward, sweeping all fascia and fat in the area in one mass. This includes dissection of fat about the ureter which should be thoroughly isolated, but left surrounded by its own vessels and fascial sheath.

7. Hinman suggests drainage by a rubber tube "placed over the aorta down to its bifurcation and swerving back above the ilium with exit at the upper back portion of the wound as for drainage of the kidney." Such a tube may cause sloughing of the aorta if placed too close to it.

8. Hinman suggests the possibility of attaching a tube of radium to the end of the rubber drainage-tube and pulling this out at intervals of one to two hours. Such a procedure does not commend itself to me.

9. The closure of the wound presents no peculiar difficulties.

Hinman reports 5 cases operated upon, with no deaths. One of these, a case of Dr. Elloesser, was well at the end of three and a half years. Of Hinman's 4 cases, 2 had metastatic gland enlargement near the renal vein. All remained well within one year of operation.

Although Coley discourages this extensive operation, it is certainly in line with modern practice in the treatment of malignant tumors. But no surgeon reporting cases has followed them long enough to prove that any large proportion of them remain well.

OPERATIVE TREATMENT OF EPISPADIAS

Epispadias complicated by incontinence of urine is not amenable to plastic treatment, but should be treated as a case of exstrophy of the bladder.

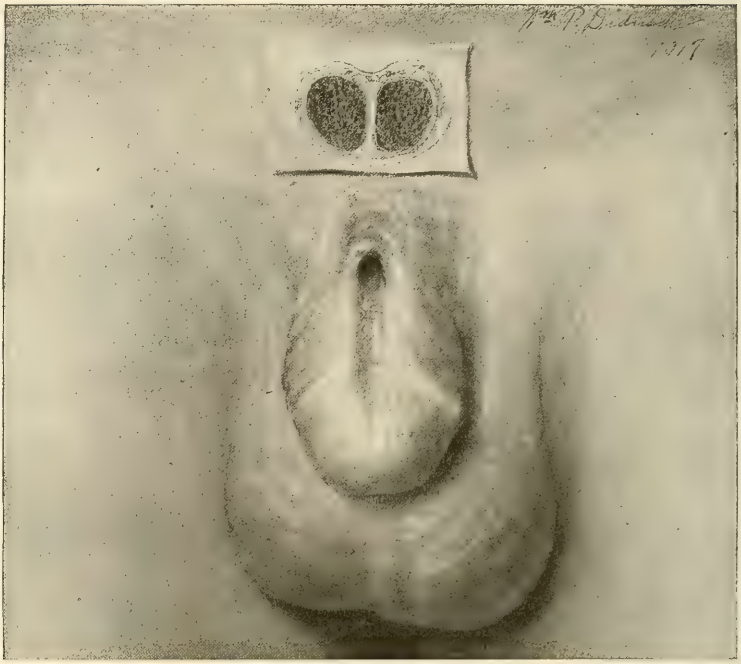

Fig. 477.—Epispadias. (Young.)

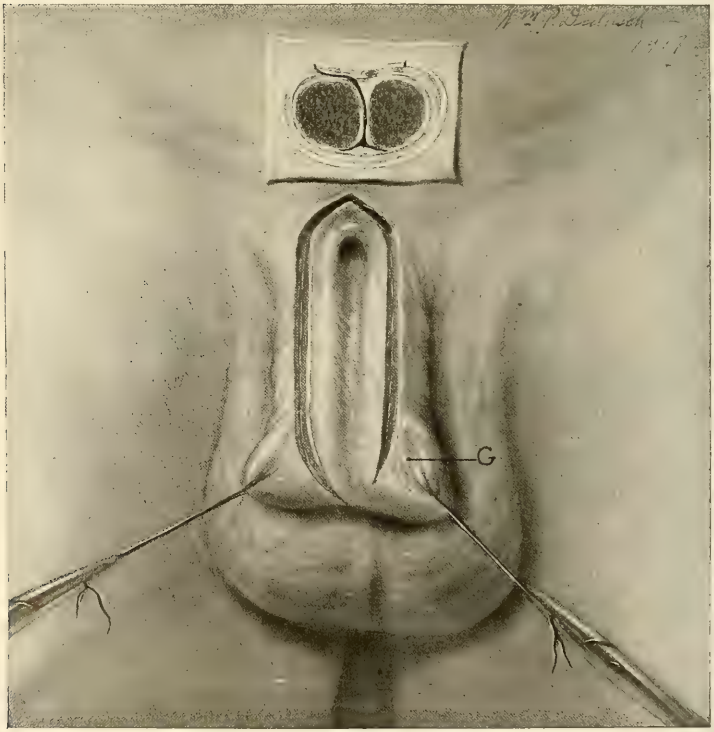

Fig. 478.—Sutures in Glans Penis. Skin Incision. (Young.)

Of the many procedures suggested for the closure of the epispadic urethra the best is the one originally employed by Cantwell, which is essentially the separation of the two corpora cavernosa and transplantation of the urethra to its normal position below these bodies.

Young has improved the technic of this operation. His method is as follows:

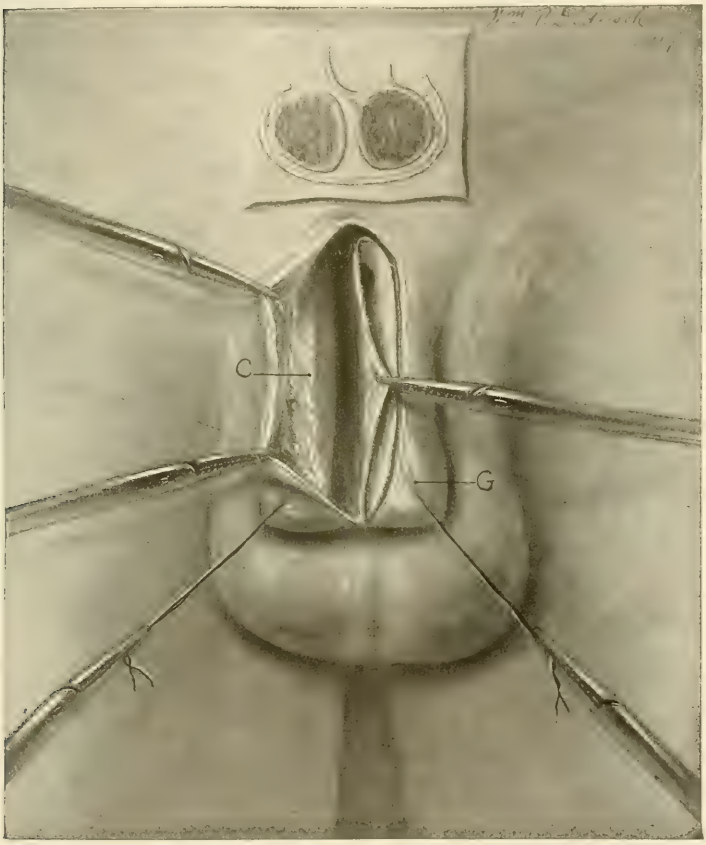

FIG. 479.—SEPARATION OF CORPORA (*C*). (Young.)

1. The urinary stream is diverted by perineal drainage.
2. The two sides of the bifid glans penis are fixed by sutures (Fig. 478).
3. The skin surrounding the epispadic urethra is incised in such a way as to permit the urethra to be subsequently sutured (Fig. 478).
4. The two corpora cavernosa are separated by slitting the septum.

This is the only really delicate part of the operation. The septum is not a solid fibrous separation, as usually depicted, and one is very likely to open one or both corpora cavernosa in separating them. If this is done, the corpora must, of course, be closed by suture. The condition after separation of the corpora cavernosa is represented in Fig. 479.

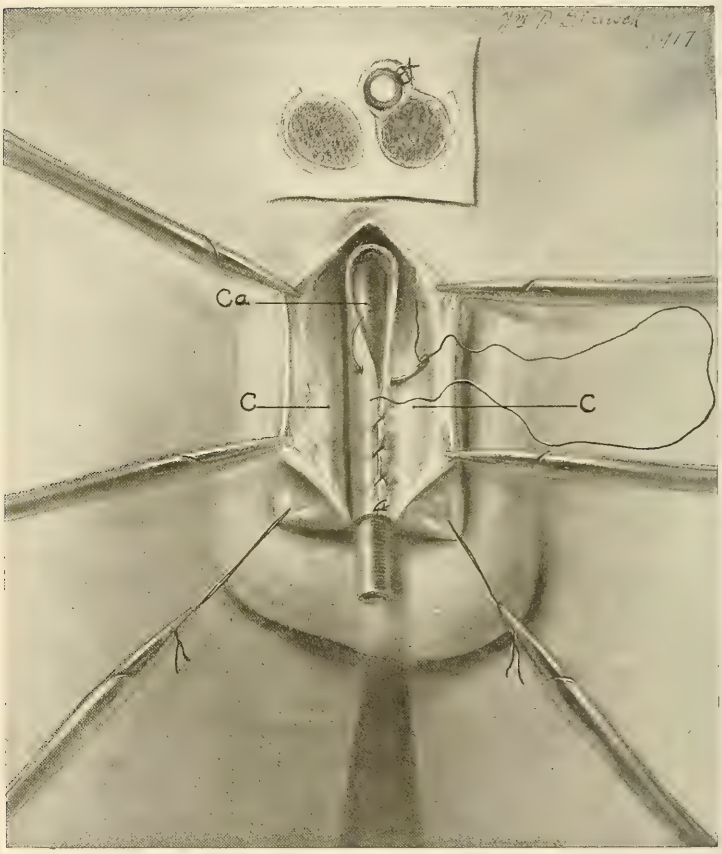

Fig. 480.—Suture of Urethra About Catheter (*G*). (Young.)

5. The new urethra is then closed over a catheter by a running suture of fine chromic catgut (Fig. 480).

6. The corpora cavernosa, to which the urethra has been left attached, is then rotated sufficiently to permit the urethra to fall into its normal place below the two corpora. These are then sutured together (Fig. 481) and the skin sutured above them (Fig. 482).

7. The catheter in the urethra is withdrawn.

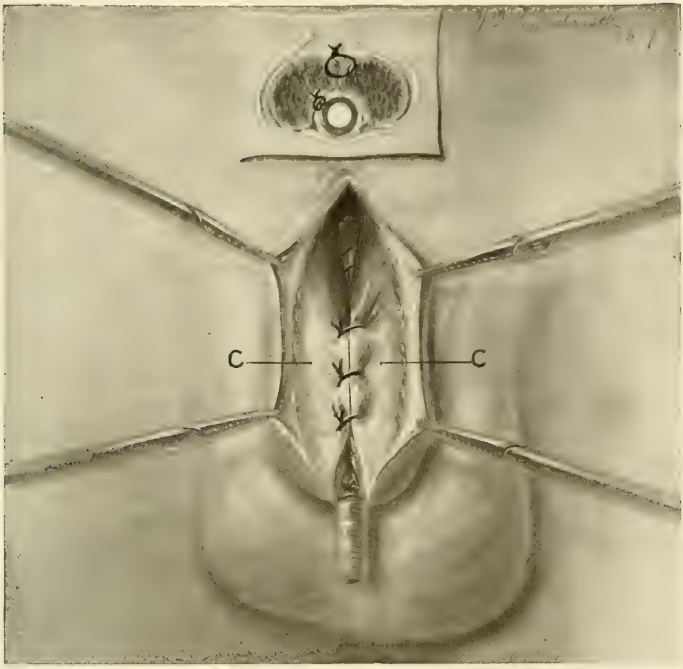

FIG. 481.—ROTATION AND REATTACHMENT OF CORPUS CAVERNOSUM. (Young.)

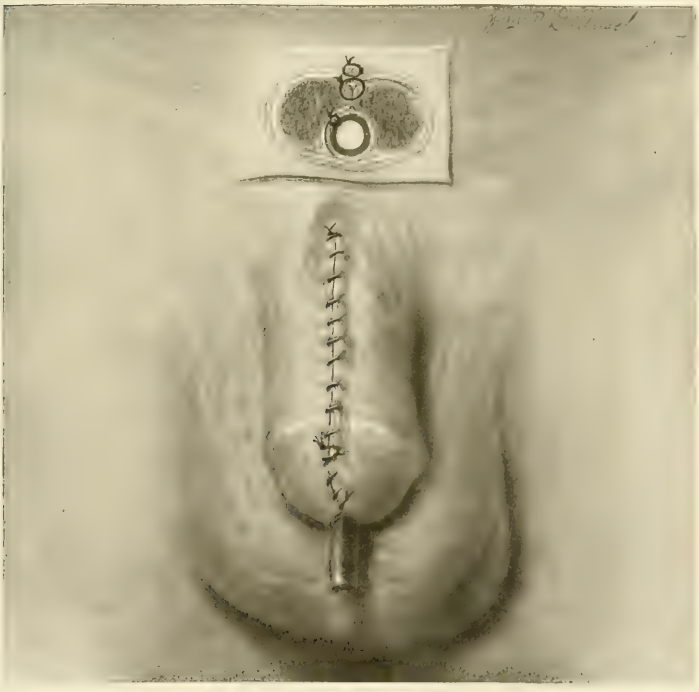

FIG. 482.—FINAL SUTURE. (Young.)

URETHROSCOPY

Urethroscopy of the anterior urethra has not been developed materially during the past decade. The external light urethroscope remains the most convenient for general use, and the light carrier that bears the name of Young is the one generally preferred. The examination of the posterior urethra has, however, been greatly facilitated by recent improvements in the urethroscope.

Water distention should be used for examination of the posterior urethra for the same reasons that make it preferable to air for examination of the bladder. (Buerger's recent modification of Geiringer's instrument is a good example of the direct vision instrument, and McCarthy's modification of Buerger's indirect urethroscope is an excellent example of that type.)

Each type of instrument has its advantages. I generally employ the direct vision instrument. With this one sees the walls of the posterior urethra and bladder neck in profile, as it were, and, by varying the flow of water, the urethra is made to flap open and shut, thus bringing into prominence any lesions that may be present.

After such lesions have been identified by the direct vision cystoscope their detail may sometimes be studied better by the indirect vision instrument. The mouths of the ejaculatory ducts and of the utricle can be seen more plainly through this indirect urethroscope.

For treatment the fulgurating wire may be employed. The utricle may also be conveniently washed out through the indirect vision instrument. For the ordinary granulations along the floor of the posterior urethra I usually employ applications of pure liquor hydrargyri nitratis very sparingly made on a wooden applicator through an open tube. I use the Geiringer or Buerger direct vision instrument to identify the lesion, then remove the cap, suck out the water, affix Young's light carrier, identify the lesion, and make the application directly to it.

Perfection in posterior urethroscopy has permitted a much better classification of the lesions of this canal than we formerly had. There is no need here to dwell on the details of lesions caused by trauma, tuberculosis, neoplasm, syphilis, or prostatic hypertrophy, with the exception of the item cited below as diagnostic of tuberculosis.

The more important lesions of gonorrheal and postgonorrheal infection are the following:

Granulations.—From time to time polyps of the posterior urethra has been described. Some of these were undoubtedly tumors, but many of them, however, were nothing more than inflammatory granulomata. The urethroscope that we now possess permits a careful study of these lesions, and we find them in almost every case of posterior urethritis and prostatitis. Their usual situation is about the verumontanum, though an extensive lesion may cover the whole floor of the urethra from the verumontanum to the mouth of the bladder, and may extend over even into the trigone. The lesion is nothing more than an unhealed ulceration with a frond of granulation sprouting from it. When with

the indirect vision urethroscope we look down upon such a lesion it appears as a red and bleeding spot in which the exuberant granulation is sometimes identified with some difficulty. The direct vision instrument used as above described, however, brings the waving little granuloma sharply into view.

These lesions are not only the commonest but also the most important of the superficial lesions of the posterior urethra. When extensive they often are the seat of a chronic gonorrhea that is defying treatment. When localized they are the cause of the morning drop and the shreds of many a case of rebellious urethritis.

The treatment of these lesions is by cauterization rather severe and infrequent through the urethroscope. I employ the liquor hydrargyri nitratis as above described once in two weeks. Great care must be taken not to permit this drug to spill about the posterior urethra, as it is a strong superficial cauterizer and will do unnecessary damage and cause unnecessary pain, but it is much more efficient than the 20 per cent. silver nitrate solution usually employed.

Cysts.—These appear as multiple pinkish or glistening projections usually about the neck of the bladder and adjacent portion of the urethral floor. They collapse when punctured or sparked with the high-frequency current. They do not seem to cause symptoms, and may be classed as pathologic curiosities.

Inflammation of the utricle may be suspected when pressure on the prostate with an indirect vision urethroscope in the posterior urethra causes the exudation of a fair amount of fluid from this cavity. It may be diagnosed by passing a ureteral catheter into the cavity, and washing pus from it. The treatment is irrigation once a week with silver nitrate solution. Inflammation of the utricle is an occasional cause of persistent chronic posterior urethritis, and often occasions painful ejaculation, and sometimes other types of perineal pain. The urethroscopic treatment should be combined with prostatic massage.

Littritis.—The glands of Littré occur on the roof of the membranous urethra. When inflamed their orifices appear reddened and exude pus. The treatment of such a condition is similar to the familiar treatment of similar anterior urethral conditions.

Lymphoid Bodies in the Prostatic Urethra an Evidence of Tuberculosis.—Pelouse describes the lesion as follows:

"If the cystoscope with the lens on the convex surface is inserted into the bladder, and with the irrigating fluid flowing is drawn into the posterior urethra, it will be found that a very good view can be obtained, almost as good as that given by the cysto-urethroscope. By rotating the instrument so as to bring the lateral ureteral wall into view there will occasionally be seen a number of small slightly pedunculated or sessile masses of tissue springing from a mucosa that seems little if at all inflamed These bodies vary considerably in size, are of a fairly white, rarely red, color, and minute blood-vessels can be seen. . . . At an early stage these are apparently solid masses of tissue that later seem to undergo a cystic change. In this cystic stage they are easily

ruptured, and a whitish substance exudes. When ruptured they leave an abraded reddish surface, usually circular in outline, with a small shred of white tissue attached to the end. Such areas may be the only evidence of urethral trouble, and should excite suspicion. . . .

"While the location of these bodies is usually upon the lateral urethral wall just inside of the vesical neck, they may occur upon almost any portion of the prostatic urethral wall or verumontanum. They also occur in the anterior trigonal angle and urethra of the female."

The solid masses are tuberculous and contain bacilli. According to Pelouse the lesion occurs exclusively in patients suffering from tuberculosis. Yet a patient with advanced tuberculosis may not show the lesion, and a patient with mild tuberculosis may have it. There may be no other tuberculous lesions of the urinary tract than this one. "Probably 50 per cent. or more of all cases of chronic follicular prostatitis which present burning at the vesical neck or in the fossa navicularis on urination will show these urethral bodies and have tuberculosis.

"There is evidence that persistent prostatic massage though indicated by the coincident prostatitis has a decided tendency to light up tuberculous foci in other parts of the body, particularly in the lungs and in the epididymi."

He does not believe that any treatment will benefit the urethral lesion.

ACRIFLAVIN IN THE TREATMENT OF GONORRHEA

Acriflavin was proposed for the treatment of gonorrhea by David and Howell, at the suggestion of Dr. Young. They found the drug an efficient antiseptic and extraordinarily penetrating. They obtained very good results with it in solutions of 1 : 1000 used once a day for hand injections into the anterior urethra, and instillations into the posterior urethra in the treatment of gonorrhea both acute and chronic.

Since this publication there has been considerable controversy as to the value of acriflavin and a great deal of unpublished criticism of it. We have not yet used it long enough to be absolutely sure of its value, or of the strength of solution or frequency of injection which is likely to be of most benefit to the average patient. The objections to the drug is its quality of irritating the urethra, *i. e.*, increasing the discharge without causing any pain at the time of injection. One is thus able to harm a patient without hurting him, a condition which permits the injudicious to use the drug with great rashness. I have used it in solutions no stronger than 1 : 2000, and no less strong than 1 : 5000. I usually inject it once a day, and sometimes alternate it with argyrol or permanganate of potassium if the discharge is very profuse. It should certainly not be retained in the urethra more than five minutes, and possibly it may work even better if held in even a shorter time. It sometimes is extremely efficient, controlling the discharge by a very few injections, and under these circumstances is more brilliantly efficient than other forms of injection. At other times it failed absolutely. Generally speaking, it seems probable that unless one gets brilliant

results from it in a few injections it is as well to have recourse to other more familiar drugs.

The same is true of its use in the posterior urethra where a single instillation may do marvels, but if two or three fail to help it is unwise to continue.

It is not evident that acriflavin is peculiarly efficacious in any other form of urinary infection than that caused by the gonococcus.

PROOF OF THE CURE OF GONORRHEA

The microscopic diagnosis of gonorrhea is extremely unreliable. The familiar urethral staphylococcus may appear as a diplococcus, may be intracellular, and may be Gram-negative. The presence of a few Gram-negative diplococci is therefore of no diagnostic significance. The presence of gonococci may only be affirmed if pus-cells are found literally crowded with Gram-negative diplococci.

Cultures are equally deceptive; they are difficult to make, and the growth of gonococci may be overrun by other bacteria.

The complement-fixation test for gonorrhea is variously estimated by different reporters. One of its evident defects is an occasional unwarranted positive reaction. Another is the persistence of a positive complement-fixation test after every other ecidence of gonorrhea has disappeared. This is especially prolonged in systemic gonorrhea, when the test may continue positive for many months after the urethral lesions have healed.

The cessation of infectiousness may be determined by a combination of urethroscopy and the complement-fixation tests as follows:

The patient is examined as to pus in the urine and in the prostate and seminal vesicles. A sound is passed to determine the caliber of the urethra, and the blood taken for a complement-fixation test.

The next morning the discharge is again examined for gonococci, and special note is made as to whether the amount of discharge has been much increased by the passage of an instrument. If there is no increase in discharge and no gonococci are found, the urethroscopic examination is made, first in the anterior and then in the posterior urethra. This will surely excite some discharge on the following day which may continue for several days, and in it the pus-cells packed with gonococci can readily be identified if any *superficial* lesions due to the gonococcus persist. In the meanwhile the report on the blood examination will disclose the presence or absence of *deeper* lesions in the prostate or seminal vesicles or elsewhere. If both tests are negative the patient may be guaranteed as cured of his infectiousness, though the lesions of the disease, such as stricture, prostatitis, etc., may persist for an indefinite time thereafter.

Pearson has used a provocative vaccine test as follows:

"On the morning of the first day a dose of 3,000,000 polyvalent gonococcal vaccine is administered subcutaneously, and at the same time the seminal vesicles, prostate, and Cowper's glands are massaged to liberate any toxins confined in them. The patient is then instructed

to hold his water from midnight of that night until a smear is taken the next morning, and to do the same for each successive night until four smears have been obtained. On the morning of the second day a dose of 5,000,000 of the vaccine is administered."

After such injections the smears gave precise evidence of the presence or absence of gonococci in 96 out of 100 consecutive cases.

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CHAPTER L

GONORRHEA IN WOMEN AND IN FEMALE CHILDREN

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Section I

GONORRHEA IN WOMEN

Frequency.—The gonococcus is the most frequent etiologic factor in the production of inflammation of the female genital tract. As the micro-organism is often difficult to demonstrate, this fact should be borne in mind when treating inflammatory lesions of obscure origin. Keyes[8] estimates that 50 per cent. of young men contract gonorrhea, and Cabot[3] places this proportion at 35 per cent. Menge[11] states that for every 5 or 6 cases of gonorrhea in the male there is 1 in the female. He bases his estimate on the fact that gonorrhea is usually contracted through illicit intercourse and that men are more licentious than women. Statistics compiled from the reports of Brose, Sänger, and Everhard[13] show that in a series of 1361 gynecologic patients 12.77 per cent. were infected with gonorrhea. The gonococcus is by far the most frequent etiologic factor in the production of pelvic inflammatory disease, the estimates varying from 30 to 90 per cent. Probably a half-way figure between these extremes would be the correct average.

Diagnosis.—Gonorrhea in the female attacks primarily three locations—the cervix, the urethra, and the vulvovaginal glands. In the acute stages, for all practical purposes, the diagnosis, even without laboratory aid, as a rule, is easily made, although the positive confirmation of the diagnosis can be made only by the demonstration of the gonococcus. However, the reddening of the suspected areas and the profuse purulent discharge make the diagnosis comparatively simple. If doubt exists, the diagnosis may be readily confirmed by examination of smears, as at this stage large numbers of typical gonococci are present in the discharge. Unfortunately, in the chronic stage the diagnosis by clinical or laboratory methods is much more difficult. At this stage the affected localities present an appearance that is often much less characteristic, and gonococci are often present only in small numbers, and not infrequently in more or less atypical forms. It is always important to know whether or not one is dealing with a case of gonorrhea or with one of the simpler varieties of inflammation. Not only should the differentiation be made early in the case, so that the patient may be warned of the danger to others as well as to herself, and in order that every effort may be made to prevent the spread of the infection to the body of the

uterus and to the pelvic peritoneum, but it is also of the utmost importance to determine when a cure has been effected and, therefore, when local treatment may be discontinued.

Owing to the large number of micro-organisms that are similar morphologically to the gonococcus, and that may be found in the female genital tract, all staining methods should be verified by Gram's test. With Gram's stain all micro-organisms that are similar morphologically to the gonococcus and that are likely to be encountered may be eliminated, with the exception of the meningococcus and the Diplococcus catarrhalis chronica. In cases in which there is difficulty in demonstrating the gonococcus, or after a course of treatment when it is necessary to determine whether or not a cure has been effected, the following points are to be borne in mind: Smears taken either immediately after the cessation of a menstrual flow, or just as the lochia is beginning to diminish after the emptying of the gravid uterus, are especially likely to contain gonococci, as at these times micro-organisms from the depths of the glands are more likely to be present. If it is necessary to obtain smears from a doubtful case at other times, the preliminary application to the suspected areas of a strong silver nitrate solution twenty-four hours preceding the taking of the smears increases the amount of glandular secretion and enhances the likelihood of demonstrating the gonococcus. A slight trauma inflicted on the suspected areas at the time of the application is also beneficial, and may easily be applied, especially to the cervix, which is poorly supplied with sensory nerves. To obtain the material for examination the patient should be so placed that a good light will fall directly on the parts in question. The exits of each of Bartholin's glands are wiped off, the glands are milked out, and the drop of secretion thus obtained is transferred to the slide.

The external urinary meatus is next wiped off, the urethra milked out, and the secretion obtained, especial effort being made to secure secretion from Skene's glands, which are situated in the floor of the urethra, their exits being just within the external urinary meatus. The cervix is next exposed, wiped off, and a drop of secretion from just within the external os secured. Each slide should be labeled with the name of the location from which the smear was taken. Secretion free in the vagina is of little value, since it is likely to contain atypical micro-organisms. A medicine-dropper the tip of which has been heated in the flame of a Bunsen burner and drawn out to about 3 inches in length and to the diameter of a coarse capillary tube is an excellent implement with which to collect the material for examination. The cotton swab often employed has a tendency to retain in its meshes the cellular elements of the discharge, and as the intracellular demonstration of the gonococcus is necessary for its identification, this is an important point. Moreover, when the cotton swab is rubbed on the glass slide it is likely to injure the cells in the discharge, and thus transform intracellular into extracellular micro-organisms. The platinum loop or the blade of a dull narrow bistoury may also be employed for collecting the material for examination, either one being superior to the cotton swab, but neither

one being so satisfactory as the medicine-dropper, which enables the examiner to secure the material from the exact area desired. It should be impressed upon the clinician that the gonococcus is often extremely difficult to demonstrate, and that frequently a number of examinations will be necessary before the organism can be found.

For this reason, in the face of clinical symptoms pointing to gonorrheal infection, it is safe to consider the case one of gonorrhea until it can be proved otherwise by at least two or more bacteriologic examinations, the material for which has been obtained under circumstances favorable for the demonstration of the gonococcus. In a case once found to be of gonococcal origin I am in the habit of continuing treatment for a week or ten days after all clinical signs have disappeared, and then making a bacteriologic examination as previously described, and if the smears are negative, allowing an interval of two weeks to elapse without treatment. I then make another bacteriologic examination, and not until three such negative bacteriologic examinations have been obtained in succession do I pronounce the case cured.

GONORRHEA OF THE LOWER GENITAL TRACT

The period of incubation is about three to seven days, occasional extremes being encountered. The cervix and the urethra are the localities generally primarily infected, the next in frequency being one or both vulvovaginal glands. The gonococcus exhibits a marked preference for cylindric rather than squamous epithelium, and, indeed, will not, as a rule, live upon the latter in the adult. As the portio vaginalis is covered with squamous epithelium, the primary infection generally takes place just within the cervical canal. As the cervix is almost insensitive, the only subjective symptom of cervical gonorrhea is leukorrhea; in the acute stage this is profuse and purulent, but soon becomes mucopurulent, and in chronic cases may be noticeable only for a few days following the menstrual period.

The female urethra measures only 3.5 cm. in length, and contains fewer glandular structures than does the corresponding organ in the male, the chief structures being Skene's glands, which have been previously alluded to. For these reasons symptoms from a gonococcal urethritis in the female are usually mild and transient in nature, a slight dysuria and frequency for a few days may be the only manifestations, and these are often so mild that in the later stages of the disease the patient may forget that they were ever present. During the acute stages there will be reddening and swelling of the mucosa, and a drop or two of purulent material can readily be expressed. In the chronic stages there are generally no subjective symptoms. Examination at this time may show no evidence of infection; often, however, if the labia urethræ are retracted the exits of Skene's glands will be seen to be slightly reddened, and a drop of mucopurulent discharge may be expressed. This "skenitis" persists long after the other symptoms of urethritis have disappeared. Occasionally an abscess in these glands develops, resulting in the so-called suburethral abscess, first described

by Hays[6] in 1805. These abscesses are usually single, but may be multiple. Gicerin[5] has described a rare condition in which follicular abscesses occurred, first one and then another follicle becoming involved. Suburethral or para-urethral abscesses usually discharge their contents into the urethra, but may rupture into the vagina and produce urethrovaginal fistula. The abscesses are generally easily diagnosed, and rarely attain a size larger than 1 cm. in diameter.

It is unusual for a gonococcal infection of the urethra to extend to the bladder. When it does so, the trigone is the area most frequently attacked. If a cystitis is suspected, the two-glass test should be employed. Because of the nature of this lesion, and the danger of carrying the infection through the medium of an instrument, cystoscopic examination is inadvisable.

Bartholinitis, or infection of one or of both of the vulvovaginal glands, is of frequent occurrence, and may manifest itself in a variety of lesions. As the gonococcus obtains entrance from without, the exit of the gland is primarily involved. This is situated just in front of the carunculæ myrtiformes, at about the junction of the middle and lower thirds, on the inner surface of the labia minora. Infection at this point results in a small reddened macula with a deep red center, which represents the exit of the gland. This lesion has been likened in appearance to a flea-bite, and is often referred to as the gonococcal macula of Sänger. Although any form of inflammation may produce this lesion, in the great majority of cases its origin is due to the gonococcus.

Cysts of Bartholin's Gland.—As a result of inflammation the duct of the gland may become occluded, and terminate in the formation of a cyst. These cysts vary in size from that of a pea to a goose egg, and contain viscid, colorless or yellowish fluid, or it may be chocolate colored from the admixture of blood. As a rule, such cysts produce comparatively few symptoms, except those due to their size, unless infection occurs either from further extension of the organism originally causing the occlusion, or from the presence of other micro-organisms. Trauma to these cysts not infrequently results in suppuration. Small cysts may be present for years without producing any inconvenience. The larger cysts are to be differentiated from hernia, hydrocele of the round ligament, true vaginal cysts, solid tumors, such as lipomata of the labia, perirectal abscesses, and particularly from hernia and cysts combined.

Abscess of Bartholin's Gland.—By some authorities an abscess of Bartholin's gland is said always to result from a mixed infection. Such abscesses are pyriform in shape, the larger end pointing downward, and are rarely more than 5 or 6 cm. in diameter, and often smaller. They are usually unilateral, but may be bilateral; they tend to rupture on the inner surface of the labia, just above the exit of the duct. They produce severe local symptoms. Their chief clinical characteristic is their tendency to recur. The vulvovaginal gland is a compound racemose structure, which has been well likened to a bunch of grapes. An abscess may form in one branch of the gland, break down, and the acute symptoms disappear, and months or sometimes even years after-

ward the infection may light up in a different portion of the gland and another abscess result. In this manner numerous abscesses may occur. A history of repeated abscesses in this locality is almost pathognomonic of gonorrhea.

Non-suppurative Bartholinitis.—Apart from the formation of cysts or abscesses in this region the vulvovaginal gland may be the seat of a chronic non-suppurative lesion, the sclerotic bartholinitis of Sänger —the gland being palpable as a firm structure.

Condylomata acuminata, or venereal warts, are a frequent complication of gonorrhea, and as they are due more or less to a constant bathing of the parts by the discharge, they are more frequent in neglected cases and among the uncleanly. Smith[15] has recorded a case in an infant nineteen months old. These warts appear most frequently on the external genitalia and perineum, and are occasionally seen in the vagina, and rarely upon the cervix. Owing to the anatomic structure of the female, venereal warts of gonococcal origin are more prone to occur in women than in men and to attain a greater size. They are to be distinguished from the warts of syphilitic origin and from carcinoma and other neoplasms. The gonococcal wart is pointed, whereas the syphilitic growth is generally flat. If any doubt exists, a Wassermann test should be made, and the excision of a small excrescence and its examination histologically will readily rule our carcinoma and other true tumors.

Taken collectively, and unless some of the above-described abscesses occur, the symptoms of gonorrhea in areas below the internal os are, as a rule, mild, and may be almost chronic from the onset. An increase in the leukorrheal discharge and a tendency for it to become purulent, particularly manifest immediately subsequent to the menstrual period and in the bride often attributed to defloration, constitute the only symptoms due to infection of the cervix. The urethritis often shows itself only in a mild frequency and slight burning that disappear without treatment in the course of a few days. The vulvitis may produce only a mild itching, which is also generally transitory, or all symptoms referable to the vulva may be entirely absent. It is natural, therefore, for the innocently infected or unsuspecting woman to neglect treatment until the disease has extended to the body of the uterus and resulted in definite symptoms generally producing salpingitis, sterility, and other accompanying conditions frequently requiring a mutilating operation for their relief. The early symptoms in the female are often almost diametrically opposite to those produced by the same micro-organism in the male. In the average case in the male the early symptoms are well defined and painful, and as a result the patient seeks treatment early and the late subjective symptoms may be almost absent. In the case of the female, however, if the disease has spread to the pelvic peritoneum, the late symptoms are well defined. On account of the mildness of the early symptoms many women do not apply for treatment until the upper genital tract has become involved, whereas in male patients it is often difficult to persuade them to continue treatment in the terminal stages of the disease.

Treatment.—In culture the gonococcus is easily killed or its growth inhibited, and the organism rendered innocuous by heat, cold, desiccation, or the application of extremely weak solutions of the ordinary bactericides, especially the silver salts. In the living patient, however, the gonococcus produces an extremely chronic disease that does not yield readily to treatment, and exhibits, especially in the female, a marked tendency to recur or at least to resist persistent and well-applied treatment. This characteristic of the gonococcus was formerly attributed to the belief that growth of the micro-organism in artificial media was extremely weak. More recently, however, it has been discovered that with better cultural methods the gonococcus can be grown quite easily, although it rarely exhibits a profuse growth and is easily crowded out by other more freely growing bacteria. One of the chief reasons for the resistance of the disease to local treatment is that the gonococcide cannot be made to reach the deeper growing organism. It seems likely that surface organisms are easily killed, and that re-infection is constantly occurring from the depths of the glands and even from the interglandular tissues. Although gonorrhea is primarily a surface infection, the gonococci soon spread to the deeper layers of the tissue, usually by way of the glands, and it is to these gonococci that the chronicity of the infection is due. The readiness with which the micro-organisms are destroyed when on the surface even of a favorable medium is proved by the efficiency of the Credé prophylactic treatment of ophthalmia neonatorum, or the more recent successes of the prophylactic measures against venereal disease in the Navy and Army.

The secret of success in the treatment of gonorrheal infection of the lower genital tract in the female consists in maintaining cleanliness and in the application of an efficient gonococcide. Owing to the anatomic structure of the genital tract in the female these ends are difficult to attain, and this is particularly true if the seat of infection is the cervix. This is due to the presence of the tenacious mucopurulent secretion of the cervical glands, which, in the event of an inflammation, is considerably increased. Preliminary treatment with an alkaline lotion, such as Dobell's solution, is most important, and if the best results are to be attained the solution should be thoroughly applied immediately prior to the employment of the gonococcide. Silver nitrate, tincture of iodin, and formalin solution in appropriate strength are reliable gonococcides. Watson[17] has recently reported excellent results from the employment of acriflavin in 1 : 1000 or 4000 solution. Colonies of gonococci are killed in two minutes by exposure to acriflavin in 1 : 4000 solution. Young, White, and Swartz[18] have recently advocated the employment of mercurochrome—220 in a solution of 1 : 1000. The more prolonged application of gonococcides by means of tampons is often advisable, and in the intervals between treatments the employment of a non-irritating mild antiseptic vaginal douche is beneficial. Local application to the urethra and other infected areas should not be neglected. Abscesses should be opened and infected vulvovaginal glands should be excised *in*

toto, all the glandular structure being removed, for otherwise recurrence is likely to ensue. Brunet[2] and Polak recommend the application of picric acid to cervical lesions. The employment of suppositories or bougies containing silver salts or other mild antiseptics has been successful in many cases. They constitute a satisfactory vehicle for the application of the gonococcide. Hunner[7] recommends in some cases the destruction of the cervical glands by the actual cautery. Following this treatment there is a marked increase in the leukorrheal discharge for a month or two, and then a definite decrease, due to the destruction of the gland-bearing tissue and the contraction of the cicatricial tissue. In my own hands this treatment has usually been employed in conjunction with one of the conservative intraperitoneal operations, where it has seemed best to conserve the uterus, and in those patients in whom leukorrhea has been a pronounced symptom. A more certain but a more time-consuming procedure is the operation of trachelectomy. Under no circumstances is a curetage advisable during this stage of the disease. Even after involvement of the corporeal endometrium has taken place curetage is of doubtful value unless performed as an accompaniment of one of the intraperitoneal operative procedures. Rawls,[12] Lincoln,[9] and others have pointed out the dangers and futility of curetage.

The treatment of condylomata acuminata is largely dependent upon the individual case. In properly treated cases these lesions rarely develop. Cleansing with a weak antiseptic solution, followed by careful drying and the application of a dusting-powder, will often effect a cure in mild cases. If this method fails, and especially if the warts are few in number and are pedunculated, they may be removed with a pair of sharp scissors and the base touched with pure carbolic or nitric acid. The surrounding surface should be protected by vaselin or other similar substance. If only one or two are to be excised, this can be done under local anesthesia. Care must be exercised that the resulting cicatrix does not produce undue deformity, which may give rise to dyspareunia or other symptoms. Freezing the base of the tumor with ethyl chlorid has been suggested, the suggestion being based on the fact that the freezing produces a thrombosis of the blood-vessels, and in a few days the tumor will drop off. This is most successful in the case of small pedunculated growths. Watson[17] reports excellent results by the use of lactic acid. Large masses are isolated and surrounded by strips of lint moistened in 0.5 to 1 per cent. lactic acid solution, and the bases of the tumors are touched at intervals with the undiluted acid. Small growths are painted with a strong solution of lactic acid or with the pure acid. Dressings are frequently changed and sitz-baths administered. I have employed this treatment with satisfaction in a small series of cases. It is especially applicable during pregnancy, as with the ordinary operative treatment there is danger of producing an abortion or inducing premature labor. When possible it is of the utmost importance to check the vaginal discharge. The x-ray or the application of radium is said to exert a marked inhibitory action on the growth of these tumors, and in many cases it may effect a cure. The use of these agents, if they are

employed at all, should be carefully regulated in the event of pregnancy because of the danger to the fetus.

Hot sitz-baths twice daily are especially useful during the acute stages of gonorrhea of the lower genital tract. So long as there is even a small amount of discharge, a vulvar pad should be worn. For details of the various methods the reader is referred to works dealing with this subject.

The treatment of gonorrhea of the lower genital tract is tedious and often discouraging; in spite of this, every effort should be made to cure these cases, not only because an uncured case often means the development of new cases or marital unhappiness, but also because of the danger of an extension of the infectious process to the upper genital tract. From time to time various statistics referable to the latter point have been presented. In probably from 15 to 40 per cent. of cases such extension takes place. When this occurs, the consequences are serious. The spread of gonorrhea from the cervix to the body of the uterus probably occurs in every case, either at or immediately following a menstrual period or at the time of or soon after the emptying of a pregnant uterus. Close questioning of a series of women suffering from pelvic inflammatory disease of gonococcal origin will almost always bring out this fact. Gonococcal vulvovaginitis in young children is by no means infrequent. In these cases in my own experience the portio vaginalis has usually been involved. Since, of course, young children neither menstruate nor become pregnant, nor, except in the rarest instances, suffer from an upward spread of the disease, this later may, at least to some extent, be viewed as a confirmatory evidence of the foregoing statement. In an attempt to prevent the upward spread of the infection the patients should be enjoined to be inactive at the menstrual period, and, if possible, should either be instructed to remain in bed or be confined to their rooms at this time. Local treatment of all kind should cease. Schindler,[14] upon the basis of a series of experiments performed by him, believes that the uterus possesses a definite rhythmic automatic movement not influenced by the central nervous system. Atropin has been found to paralyze this movement. On the basis of this finding Block[1] has recommended atropin in cases of spasmodic dysmenorrhea, and I have employed it with moderate success in the same class of cases. The exhibition of atropin at the periods when extension into the body of the uterus is likely to occur is, therefore, indicated. Watson[17] believes coitus to be a potent factor in causing upward extension of the disease.

Finally, all patients suffering with gonorrhea must be warned of the nature of the disease. Although in some cases it is doubtless inadvisable actually to inform the patient that she has gonorrhea, she must be warned as to the necessity of observing prophylaxis as regards others, and of the danger to her vision if the vaginal discharge is carried to the eyes. In the married patient an effort should always be made to have the husband examined by a genito-urinary specialist. Obviously, no rule can be formulated regarding the attitude to be assumed in all cases,

and often much tact and discretion are required in dealing with these patients. The absolute futility of applying local treatment to a woman who is constantly being subject to re-infection is obvious.

GONORRHEA OF THE UPPER GENITAL TRACT

If the infection spreads from the mucosa of the cervix to that lining the body of the uterus an extension from the corporeal endometrium to the mucosa of one or both tubes is likely to take place within a short time. Indeed, the first evidence that the disease has spread upward from the cervix is often an attack of salpingitis. Frequently the first attack is unilateral, and the remaining side may or may not become infected during subsequent exacerbations. In the genital tract of the female the gonorrheal affection extends by continuity along the mucosa, and later the deeper tissues become involved. When the tubal mucosa is involved, an irritating secretion is formed, a portion of which escapes through the abdominal ostium of the tube. This produces at first a peri-oöphoritis, and may subsequently result in oöphoritis. In the latter event the gonococcus may gain entrance to the substance of the ovary by direct extension from the surface or through the rupture of a follicle. Abscesses may result, but these are less frequent than in the streptococcus type of infection. The escape of pus from the tube not only produces ovarian lesions but also involves the adjacent peritoneum as well, resulting in the formation of numerous adhesions. Nature attempts a cure by sealing the ends of the tube, in which event either a pyosalpinx or a hydrosalpinx results. This occlusion may be a permanent one, or subsequent leakages may occur that produce renewed acute attacks and further damage the pelvic contents. In some cases, especially when a hydrosalpinx is present, the occlusion of the uterine end of the tube may be overcome, and the tubal contents empty themselves through the uterus with a concomitant alleviation of symptoms, followed by a gradual refilling of the tubal sac and a recurrence of the symptoms.

This may be repeated a number of times, and in some cases at fairly regular intervals. This lesion constitutes the so-called recurrent hydrosalpinx, or the hydrops tubæ profluens of the older writers. It is my own opinion that the corporeal endometrium attacked by the gonococcus manifests a tendency to undergo a spontaneous cure. That this is undeniably true in a certain percentage of cases is proved by the fact that in many instances no histologic or bacteriologic evidence of inflammation is present, and when it is observed, it will almost invariably be found in conjunction with tubal lesions that, by leakage through their uterine end, tend to prolong the infection. The leukorrhea from which many of these patients suffer is generally cervical in origin. The gonococcus rarely produces a general peritonitis, the infection being nearly always limited to the pelvis.

In the final stages of the disease the symptoms are often the result not of an active infection, but of the adhesions and distortion produced by former acute attacks. In other words, such residua are the "derelicts of the gonococcal storm," as Sänger has so aptly termed them. Encap-

sulation tends to destroy the gonococci so that cultures from purulent accumulations are frequently found to be sterile. Secondary infection by other micro-organisms is of frequent occurrence. It will readily be seen that the gonococcus may produce numerous intraperitoneal pelvic lesions, many different types often being represented in the same case. Such lesions are frequently indistinguishable until the abdomen is opened, and for want of a better term the somewhat vague designation, "pelvic inflammatory disease," is frequently applied to these conditions. Palpation and the subjective symptoms sometimes do not furnish sufficient evidence to permit a differentiation to be made between pelvic inflammatory disease due to the gonococcus and that due to some other micro-organism. For practical purposes pelvic inflammatory disease may be divided into three groups, although organisms other than those named are occasionally the causative agents:

(1) The gonococcal form, which constitutes about 55 to 60 per cent. of all cases. (2) The ordinary pyogenic micro-organism, which produces about 30 per cent. of these cases. (3) The tuberculous, which occurs in from 3 to 10 per cent. The differential diagnosis between these three types is not always possible, but can be made with a moderate degree of certainty in the majority of cases. The table on pages 632 and 633 illustrates the chief differential points in these three types of infection.

Atypical cases of acute pelvic inflammatory disease, especially when unilateral, may be mistaken for a variety of conditions, among the most frequent of which are ectopic pregnancy, appendicitis, and small or medium-sized ovarian neoplasms, especially those that have undergone torsion, rupture, infection, or gangrene. The making of a correct diagnosis is important, as the conditions just named usually require early operative intervention, whereas the uncomplicated acute pelvic inflammatory case does not.

One of the greatest advances in gynecologic surgery within recent years was the founding of the now generally accepted belief that *it is unwise to operate during the acute stage of pelvic inflammatory diseases.* Only in rare instances is operation indicated at this time. Rupture or torsion of inflammatory adnexa, a local peritonitis that threatens to become general, the presence of pus that can be evacuated without traversing the general peritoneal cavity, as in the case of a pelvic abscess pointing into the vagina, or those rare cases that resist palliative treatment for a long period—these are the only instances in which operative intervention is indicated during the acute stage. In view of our present knowledge the old dictum, "When in doubt, operate," should be revised. Instead of rushing the case of acute pelvic inflammatory disease to the operating room, far better results, as regards both the mortality and the morbidity, can be obtained by resorting to palliative measures. The patient should be placed in the Fowler position and heat should be applied to the lower abdomen. This is most satisfactorily accomplished by means of the electric pad. Lacking this, hot-water bags or even cloths wrung out in hot water may be employed. A hot vaginal douche of 1 gallon to $1\frac{1}{2}$ gallons of weak antiseptic solution should be administered

DIFFERENTIAL DIAGNOSIS OF THE COMMON FORMS OF ACUTE PELVIC INFLAMMATORY DISEASE

Gonococcal.	*Ordinary pyogenic micro-organisms.*	*Tuberculous.*
Age: During the actual sexual life.	Age: During the actual sexual life.	Age: Occasionally occurs earlier than the other varieties, and may occur later, especially when secondary to a general tuberculous peritonitis.
Previous history: Symptoms suggestive of gonorrhea in the lower genital tract, profuse or purulent leukorrhea, labial abscesses, particularly if they follow a suspicious intercourse.	Previous history: Frequently follows attempts at abortion or other intrauterine procedures upon the pregnant uterus, either at or before term.	Previous history: Genital tuberculosis is nearly always secondary. Close questioning will usually elicit a history suggestive of tuberculosis in other parts of the body, a tendency to colds, a pleurisy, or, more rarely, an osseous or other tuberculous lesion.
Time of onset: At or following soon after a menstrual period, parturition, or abortion.	Time of onset: Follows labor or abortion or intrauterine operations, especially upon the pregnant uterus.	Time of onset: No such history as in the other conditions. May occur at any time, sometimes preceded by general peritonitis.
Character of attack: Only moderately severe.	Character of attack: Often extremely severe.	Character of attack: Onset may be acute or nearly chronic.
Temperature: 100° to 102.5° F.	Temperature: 100° to 106° F.	Temperature: 99° to 103° F.
Pulse: In proportion to or lower than would be expected with the existing temperature. A good quality.	Pulse: Often higher than would be expected with the existing temperature. Often of poor quality.	Pulse: In proportion to temperature.
Respiration: Usually in proportion to pulse.	Respiration: In proportion to temperature.	Respiration: May be increased as a result of pulmonary lesion. The latter, however, is often quiescent at the time of the peritoneal attack.
General condition: Often good; although the patient is ill she does not have the appearance of being in a dangerous condition.	General condition: Often bad; the patient is the recipient of large doses of toxins.	General condition: Often below par, and may be bad as a result of the primary lesion. The pelvic peritonitis itself produces only moderate prostration.

Gonococcal.	*Ordinary pyogenic micro-organisms.*	*Tuberculous.*
Usual evidence of a moderately mild pelvic peritonitis, which exhibits no tendency to become general.	Usual evidence of a severe pelvic peritonitis which may become general.	Peritonitis may be confined to pelvis or general, or the one type may resolve into the other, generally it is rather subacute.
No bacteremia.	Bacteremia often present.	No bactermia except in rare instances.
Duration: Usually lasts five to ten days, and is followed by a chronic stage of moderate health interspersed by acute attacks.	Duration: A severe attack, from which, if patient recovers, there are no subsequent recurrences.	Duration: It runs a chronic course. Sometimes followed by similar attacks or by the development of a general tuberculous peritonitis.
Unilateral or bilateral.	More often unilateral.	Nearly always bilateral.
Prognosis: Good for life, but bad for complete recovery; generally followed by a similar attack, with, in the interim, sterility, dysmenorrhea, and more or less invalidism.	Prognosis: Mortality 5 to 15 per cent. If recovery from acute attack ensues prognosis is good.	Prognosis: Patients are prone to subsequent attacks, or may develop general peritonitis. The patient is tuberculous.
Pelvic examination: Lower genital tract, evidence of gonorrhea. Bacteriologic examinations may show gonococcus. Defloration.	Pelvic examination: The evidence of previous pregnancy. Defloration. Absence of signs of gonorrhea. Streptococci may be demonstrable.	Pelvic examination: No evidence of pregnancy or gonorrhea. Defloration incidental, and may be absent. Pelvic inflammatory disease in the virgin nearly always of tuberculous origin. By careful bacteriologic examinations tubercle bacillus may sometimes be demonstrated in the uterine discharge.
Palpation: Mass often sausage shaped, in locality of tube, frequently adherent to uterus, and generally only moderate cellulitis.	Palpation: Cellulitis often chief lesion, unless ovarian abscess is present, hence chief lesion is lower and there is more induration in base of the broad ligament than in the gonococcal case.	Palpation: Cellulitis not especially marked. Chief lesion in tubes.
Yields readily to palliative treatment.	Usually yields to palliative treatment and outcome generally decided in few weeks.	Often persists over long periods despite palliative treatment.

twice daily. These douches should be given slowly, and are indicated in all cases except in those following parturition or abortion, or during a menstrual period. Stengel and Hopkins[16] and Ludin[10] have shown that hot applications to the abdomen do not markedly increase the temperature of the intraperitoneal organs beneath, but this does not militate against the comfort and relief of pains that such applications produce. Some authorities recommend the application of cold, but in my own hands heat has given better results. The bowels should be regulated by means of a mild cathartic, so that one or two soft movements are had daily. The diet should be either liquid or "soft," depending upon the severity of the individual case. It is worthy of note that if enemata are to be employed the anal region should be carefully cleansed with an antiseptic solution prior to inserting the rectal tube. This locality is frequently soiled by gonococci-bearing discharges. Gonococcal proctitis, while not common, is by no means unknown. Opium or its derivatives may be required for pain. During the acute stage pelvic examinations should be few in number and performed as gently as possible. Fresh air is of great benefit to these cases.

These are the sheet-anchors of the treatment, and with their adoption acute symptoms will rarely persist for more than a week or ten days. By this course of treatment some cases can be spared operation entirely. During the chronic stages many of the organisms previously active and virulent are destroyed or their activity inhibited. Structures that would formerly have been removed may be saved, and as pelvic inflammatory disease is an infection occurring during the period of active sexual life, ovarian conservation is of the greatest importance. By operating during the chronic stage, drainage can be almost dispensed with, and there will be shorter convalescence, less numerous adhesions, and fewer ventral hernias. Whether or not to operate after a patient has been carried through an acute attack is sometimes a difficult point to decide. Certainly the tendency among the best informed surgeons is to operate upon fewer cases than formerly. Experience has amply demonstrated the ability of the peritoneum to effect cures that formerly would have been deemed impossible, and it is these border-line cases that will tax the judgment and experience of the surgeon. Each case must be studied individually, and no hard-and-fast rules can be carried out with success. Certain it is that in many of these cases operation will be demanded, or they will be subjected to subsequent attacks. This is the rule rather than the exception. In the interest of ovarian conservation it is often wise to operate before too much damage has been done. Thus a case of bilateral salpingitis may be subjected to bilateral salpingectomy, and if the intramural portion of the tube is removed, as it should be, the infection, if it still exists, will practically be walled off from the peritoneal cavity. As corporeal endometritis, if present, has a tendency to go on to spontaneous cure, the patient is likely to be entirely relieved of her symptoms, with the exception, perhaps, of the leukorrhea, which may persist if the cervix is untreated; furthermore, menstruation will continue, and while she is sterile, this condition existed prior to the

operation, and was due to the disease process. If, on the other hand, operation is postponed too long, serious damage will probably have been done to one or perhaps to both ovaries, necessitating a complete operation and the sacrificing of both ovaries.

Supravaginal hysterectomy and bilateral salpingo-oöphorectomy will cure nearly all these cases, but the end-results, due to sterility and the artificial menopause, are often so disastrous that conservative surgery should be practised whenever possible. A few years ago Dr. John G. Clark and myself[4] analyzed a series of cases operated upon for pelvic inflammatory disease with the idea of determining not only the immediate but also more particularly the end-results. As a result of this study the following conclusions were reached: (1) With few exceptions all cases of acute pelvic inflammatory disease should be subjected to a course of preliminary treatment before operation is undertaken. (2) If pus is present and can be reached without traversing the peritoneal cavity, it should be evacuated at once. (3) The end-results of salpingostomies are, as a rule, disappointing. Pregnancy rarely takes place, as the newly formed ostium quickly becomes occluded and results in a recurrence of the symptoms. (4) Conservation of a grossly normal tube in the presence of diseased appendages on the opposite side offers good results, especially if a course of preliminary treatment has been carried out prior to the operation. (5) Conservation of macroscopically diseased tubes is unsatisfactory, and in gonococcal cases the tendency should be to remove doubtful tubes and conserve doubtful ovaries. (6) Conservative ovarian surgery offers excellent results, provided (*a*) that the ovary is in moderately good condition; (*b*) that it can be left with an adequate circulation; (*c*) that it be left in good position; if the broad ligament is puckered, the circulation will be impaired, and a similar condition will result if the ovary is allowed to prolapse; (*d*) that raw surfaces be peritonealized. The excellent results obtainable by bilateral salpingectomy in suitable cases is strikingly exemplified in our series of 48 cases, the end-results of which were traced, as not a single patient required secondary operation, and nearly all were free from symptoms. (7) In selected cases ovarian resection offers excellent results. If a small amount of ovarian tissue is left behind, it will usually avert the sudden onset of the menopause. The reason that many resected ovaries give trouble is because of the interference with the blood-supply. (8) When it is found necessary to remove both ovaries a hysterectomy should nearly always be performed. Such uteri are useless, and may give rise to subsequent trouble. (9) A curetage and iodinization of the uterine cavity should precede all abdominal operations for pelvic inflammatory disease. Areas of infection in the lower genital tract should subsequently receive appropriate treatment.

Should it be decided not to operate upon a case of pelvic inflammatory disease that has been carried through an acute attack, the patient should by no means be discharged as cured, but should be warned of the possibility of a subsequent attack, and should be kept under observation. A copious warm douche should be taken daily except during the men-

strual period, and hot sitz-baths administered twice weekly. The bowels should be regulated. Especial care should be exercised to avoid trauma to the pelvic organs, and particular safeguards instituted at the menstrual period. In the meantime the patient should report at regular intervals for examination, and should be kept under observation for at least a year.

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Section II

GONORRHEA IN FEMALE CHILDREN

Frequency.—The gonococcus is the most frequent etiologic factor in the production of inflammatory lesions occurring in the genital tract of female children. The vulva and the vagina are the structures most often attacked. Hurden[1] was able to demonstrate the gonococcus in these regions in 63 per cent. of such cases. These figures correspond closely to my own findings. The disease is more common among the ignorant and uncleanly than among the patients seen in private practice. Holt[2] states that the disease is present in from 2 to 10 per cent. of

all inmates of institutions, such as foundling homes, asylums, and children's wards in hospitals, etc. So prevalent is the infection that in many hospitals the authorities have instituted a routine bacteriologic examination of all female infants and children prior to admitting them to the children's wards. The prevalence of vulvovaginitis in the young and its comparative infrequency in the adult may be accounted for by the susceptibility of the immature squamous epithelium in this region to the gonococcus. In the adult the lining membrane of the vagina is thicker, and toward the introitus manifests a tendency to develop an outer horny layer, such as is present on the skin. This also serves as a protective medium.

Modes of Infection.—The disease is usually propagated by accidental infection. The infecting agents may be contaminated clothing, towels, instruments, bathtubs, etc. Toilet seats are perhaps the most fertile source of accidental infection. Many cases have been recorded that have resulted from indirect infection from a parent or relative, the history often showing that the child occupies the same bed with its mother or sister who was suffering from an uncured vaginal discharge. Although the gonococcus is easily inactivated or killed by exposure to heat, cold, or drying, nevertheless the manner in which this infection can be spread through a children's ward is startling, and formerly led to the belief that the disease was air-borne. This theory is now known to be incorrect. Pearce[3] suggests that gonococcal vulvovaginitis in children may be the result of a particular strain of gonococci. If this were definitely proved to be the case it might account for the peculiar infectiousness of the disease. Less frequently the infection may be transmitted through rape, the infectionist, the sadist, precocious sexual intercourse, or during the passage of the infant through the birth canal.

Symptoms.—The onset may be acute or almost chronic. In the former event the areas are red, swollen, tender, and bathed in a profuse purulent discharge, which, in severe cases, may be blood streaked. In individual cases the symptoms may vary from those just mentioned to the mild ones in which slight reddening and a moderate amount of discharge are the only demonstrable evidences of the disease. As the symptoms of acute infection subside, moderate discharge and slight reddening are the only manifestations. In severe and especially in neglected cases the areas surrounding the introitus and those situated posteriorly toward the anus may become excoriated, and brownish crusts may form that, upon removal, leave an oozing or bleeding surface. Occasionally condylomata may occur. In practically all cases the vaginal portion of the cervix is involved, and it is here and in the various folds of the vagina and in the crypts about the external genitalia that the disease persists.

As has been stated, cases vary markedly in severity; thus one case may be of sufficient gravity to cause intense suffering, partial relief from which can be gained only by lying with the thighs widely separated; whereas another may produce nothing more than a slight reddening, swelling, and a moderate amount of discharge. Urethritis is present in

about 20 per cent. of cases; ardor urinæ may, however, be present without involvement of the urethra. The acute stage is usually of short duration, but the chronic stage may be greatly prolonged, and this despite careful treatment. Because of the chronicity and often mildness and even absence of clinical symptoms, caution should be exercised in pronouncing any case cured. The disease occurs in the immature, and in my experience rarely persists until the onset of menstruation. This clinical fact is due probably to the development of the lining membrane of the vagina prior to the onset of puberty. If this were not the case pelvic inflammatory disease of gonococcal origin in young girls would be common instead of infrequent.

Complications.—Bartholinitis and condylomata acuminata are not infrequent, and differ in no essential from similar conditions in the adult.

Cystitis is infrequent.

Proctitis occurs in about 1 to 5 per cent. of cases. Kaumheimer[4] believes the condition more frequent than is generally supposed. The temperature should not be taken per rectum in suspected or known cases, owing to the danger of infection.

Corporeal Endometritis, Salpingitis, Oöphoritis, and Pelvic Peritonitis.—The infection rarely spreads upward beyond the internal os, and as a result pelvic inflammatory disease in infants and young children suffering from gonococal vulvovaginitis and cervicitis is of extremely infrequent occurrence.

General Peritonitis.—Infection may reach the peritoneum by direct extension from the uterus and tubes, or the condition may be of systemic origin, the latter being the more frequent. Gonococcal general peritonitis is infrequent, but is probably somewhat less rare in children than in adults.

Inguinal Adenitis.—This occurs in about 15 per cent. of cases of gonococcal vulvovaginitis, and the gland breaks down in about 2 per cent. of cases.

In the adult female the so-called metastatic or systemic gonorrheas occur infrequently, except during pregnancy and the puerperium, at which times they are by no means rare; prior to puberty, however, such complications are comparatively common, the most frequent variety taking the form of an arthritis. Holt[5] states that a pyemic arthritis occurring in an infant is more frequently due to the gonococcus than to any other micro-organism. The wrist, elbow, ankle, knee, fingers, toes, and other small joints are those usually attacked. Arthritis occurring in infancy or childhood presents no marked difference from a similar lesion in the adult, except that the constitutional symptoms are prone to be more pronounced. If a systemic infection takes place, other metastatic lesions similar to those that occur in the adult may result.

Diagnosis.—It is of the utmost importance in any given case of vulvovaginitis to determine the etiologic factor, not only that suitable treatment may be instituted but also that prophylactic measures, as regards both the patient and others, may be undertaken. It is also im-

portant to be able to determine when a cure has been effected, and when treatment can, therefore, be discontinued. Like gonorrhea of the lower genital tract in the adult, the diagnosis in this form of the disease in the ordinary frank case presents few difficulties during the acute stage. In the chronic the bacteriologic examination is often attended by negative findings. All cases presenting clinical symptoms of gonococcal vulvovaginitis should be regarded as such until proved otherwise by bacteriologic examinations performed under circumstances favorable for the detection of the organism. After a course of treatment, and following the entire disappearance of clinical symptoms, the case should not be pronounced cured and treatment discontinued until at least three bacteriologic examinations, undertaken at two-week intervals, have given negative results. A satisfactory routine for examination of suspected cases is the following: Smears are made, preferably taken from well within the vagina by means of the medicine-dropper. The advantages of the medicine-dropper over the ordinarily employed cotton swab have been mentioned under the diagnosis of gonorrhea in the lower genital tract of the adult. If a cotton swab is to be employed, it should be moistened. The smear may be examined at once, and if found negative for the gonococcus, or if an insufficient amount of material was obtained, the following procedure is adopted: The child is held in the arms of the mother or nurse, or placed on the edge of a table with buttocks elevated; the external genitalia are thoroughly wiped off with cotton saturated in weak mercuric chlorid solution. By means of a medicine-dropper or an all-rubber eye syringe 3 or 4 drams of a 1 : 4000 mercuric chlorid solution made up in isotonic salt solution are introduced into the vagina, and sucked in and out of the syringe a number of times. At the same time the nozzle of the syringe is moved about in an effort to detach particles of the secretion that may be adherent to the vaginal walls. After the vagina has been thoroughly washed in this manner the solution is withdrawn and later centrifuged somewhat slowly and the sediment examined. After the withdrawal of the washings the vagina should be dried with cotton. If the patient was placed with the buttocks well elevated and the bladder and rectum were empty, the vagina will have been found to balloon out as the air or solution enters it. This last is of importance, as it smooths out the folds of the vagina, facilitating removal of the discharge, and aiding in the subsequent treatment. After drying the vagina as thoroughly as possible by the ordinary means it is well to use the drying bulb ordinarily employed by dentists. As a final step a 5 to 10 per cent. silver nitrate solution should be applied to all parts of the vaginal surface, including the portio vaginalis. If the first washings are now found to be negative for gonococcus, second washings should be taken twenty-four hours after the application of the silver nitrate solution. The silver nitrate acts as an irritant and increases the discharge, and the second washings are, therefore, more prone to contain gonococci. The medicine-dropper should be sterilized before use and the examiner should wear rubber gloves. In a clinic where a number of washings are made daily the use of a pair of motor

goggles for protecting the eyes is advisable. Rubber gloves, sterile apparatus, and goggles also have a good effect upon the parent, in that their use emphasizes the infectious character of the disease. The employment, at the second visit, of a small or medium-sized Kelly cystoscope, and the obtaining of a smear directly from the cervix prior to the second washing, are advisable. For obtaining the material a long capillary tube with a bulb attached may be used, or, lacking this, a platinum loop may be employed. In children beyond a certain age it is important to gain their confidence and to avoid giving them pain during the examination, in order that their co-operation may be secured when subsequent treatment is instituted. When possible, it is advisable to ascertain the source of infection, to prevent further dissemination of the disease, and for this reason other members of the family, especially the mother and sisters, should be examined. The infected child should not be permitted to use public toilets. Prophylaxis along these lines is an important part of the treatment and is too often neglected. The parents of the child must be warned of the danger to the eyes. In some instances it has been found necessary to point out to an ignorant mother that the disease was contracted innocently. DeSchweinitz[6] and Holloway[7] have directed attention to the frequency of gonorrheal conjunctivitis in young girls. The condition is often associated with epidemics of vulvovaginitis, and results either from auto-infection or from contamination by towels, clothing, and the like. Prophylaxis is an important part of the treatment of each case, and the danger to other children through the medium of infected clothing, towels, etc., should be made plain. The importance of continuing treatment not only until all clinical symptoms disappear but also until the satisfactory bacteriologic examinations have been made should likewise be emphasized. In conclusion, it cannot be too strongly urged that the method of examination by means of washings, preceded by the application of an irritant in doubtful cases, is always to be employed. This method was suggested by Van Gieson[8] in 1910. In 1915 I[9] reported a series of cases in which this method was employed, and described certain modifications, including the preliminary application of an irritant. Later in the same year Trist and Kolmer,[10] in an excellent article, advocated the method and suggested the addition of isotonic salt solution to make up the mercuric chlorid solution employed in the washing. The last-named authors reported a series of cases and compared the bacteriologic findings in 25 cases, all studied by vaginal smears, cervical smears, and vaginal washings; 10 of these showed gonococci in the vaginal smears, 11 in the cervical smears, and 15 in the vaginal washings, but in not a single case were gonococci demonstrated in either of the smears named without their being also found in the vaginal washings. The demonstration of gonococci depends upon the intracellular location and upon the use of Gram's stain. Well-made smears are an important part of the technic.

Vulvovaginitis may be caused by organisms other than the gonococcus. Thus, the Klebs-Löffler bacillus may produce an inflamma-

tion in this region. It usually occurs in conjunction with diphtheria of the throat or nose. The pneumococcus has been reported as the causative agent in some cases. In children below normal various other organisms have been held to be the etiologic factor. These cases are often associated with threadworms in the rectum. As has been stated, the gonococcal form of vulvovaginitis is decidedly the most frequent, and exhibits greater chronicity than do the other varieties.

Treatment.—In this, as in the treatment of any form of gonorrhea of the lower genital tract, cleanliness and the application of an efficient gonococcide are of the utmost importance. Various antiseptic applications have been recommended, but silver nitrate is one of the best. Daily injections with weak creolin, lysol, or potassium permanganate solution are beneficial. The employment of bougies containing a weak gonococcide, and which melt at body temperature, are especially applicable to those cases in which daily treatment cannot be carried out.[11] In my own practice[11] the following method of treatment has given the best results: As a preliminary measure and to aid drainage and facilitate treatment in many cases wide stretching of the hymen or its removal has been found advisable. The vagina is freely irrigated with a large quantity of a weak antiseptic solution. The buttocks are elevated or the child may assume or be held in the knee-chest position. The vagina is then ballooned out, when fold and crypts either disappear or are rendered more easily accessible. A good exposure may also be obtained by using a small wire speculum and placing the patient in the elevated lithotomy position. This speculum must be a small one. It is especially useful in infants or in those children who are inclined to cry or to strain. Good exposure and moderately wide dilatation are essential points in the treatment. With the vagina dilated its entire surface is thoroughly gone over with a 15 or 25 per cent. argyrol solution, applied by means of a small cotton swab. The argyrol is allowed to remain for a few minutes, and the vagina dried with a thin strip of soft gauze. Further drying is then effected by means of a dentist's air bulb. The dilatation of the vagina is maintained for from fifteen to thirty minutes, at the end of which time the now clean and dry vagina is painted with a weak silver nitrate solution. This treatment is administered either daily or triweekly. It is based upon the following facts: Desiccation and room temperature destroy the gonococcus and even for a short time tend to inhibit its growth. The treatment serves to develop the vaginal lining. By moderately wide dilatation, secured either by means of the knee-chest position or the wire speculum, thorough cleansing, followed by the application of silver nitrate to all affected parts, is rendered possible.

Much of the success of any form of treatment depends upon the thoroughness with which it is carried out. The careless instillation, often at irregular intervals, of various solutions is of little value in the treatment of this disease.

Serum or **vaccine therapy** has been strongly advocated by some authors in the treatment of gonococcal vulvovaginitis. My own ex-

perience with this form of treatment has been limited, and in cases that have personally been observed the results have been negative. Watson[12] has had a similar experience, and states that in some cases it seemed to determine a recurrence and in others to invite complications.

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CHAPTER LI

TROPICAL SURGERY*

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Elephantiasis.—Of the subjects treated in previous volumes under the head of Tropical Surgery, certain advances in the treatment of elephantiasis of the extremities, usually the leg, seem to call for further comment.

The chronic inflammatory hypertrophy of the skin and subcutaneous tissue, to which the name elephantiasis is given, is always preceded by venous and lymph-stasis of the part, but is directly caused by infection of the swollen tissues with streptococci morphologically identical with the streptococcus of erysipelas. Repeated infections occur, often attended with fever and constitutional symptoms, each attack adding to the size of the limb, which eventually may reach enormous proportions. Whatever the cause of the lymph-stasis, obstruction to the venous and lymphatic circulation alone will not produce elephantiasis. For this streptococcic infection and resulting inflammatory tissue changes are required.

In tropical countries, where endemic elephantiasis is very common, the agent producing lymph-stasis is usually, as we have seen, the parent worm, Filaria bancrofti, but elephantiasis is not very rare in temperate climates following obstruction of any nature to the venous and lymphatic circulation in a part of the body wherever there has also been infective inflammation producing hyperplasia of the connective tissue of the skin and subcutaneous tissues and a chronic lymphangitis. The present knowledge of the subject has been admirably summed up by Matas.[1]

As we have seen in previous chapters, the treatment of elephantiasis of the scrotum (or vulva) by total removal of all diseased tissue is an entirely practicable and satisfactory procedure, but in elephantiasis of the leg, short of amputation, operative measures have so far been only partially successful, although the relief of the deformity, if not complete, has often proved great enough to justify operation.

Total decortication and extensive skin-grafting is seldom if ever advisable in elephantiasis of the limbs. Lymphangioplasty, as practised by Handley in 1908 (see Vol. VI), has been used by others with but limited success. The operation has been practically abandoned, and Castellani's injections of "fibrolysin" have also proved of doubtful value.[2]

* Supplementary to Chapter LXVIII, Vol. IV, p. 1075, and Chapter CXLI, Vol. VI, p. 788.

FIG. 483.—LINE OF INCISION ON THE OUTER SURFACE OF THE LEG AND THIGH. (Sistrunk, in "Jour. Amer. Med. Assoc.," 1918.)

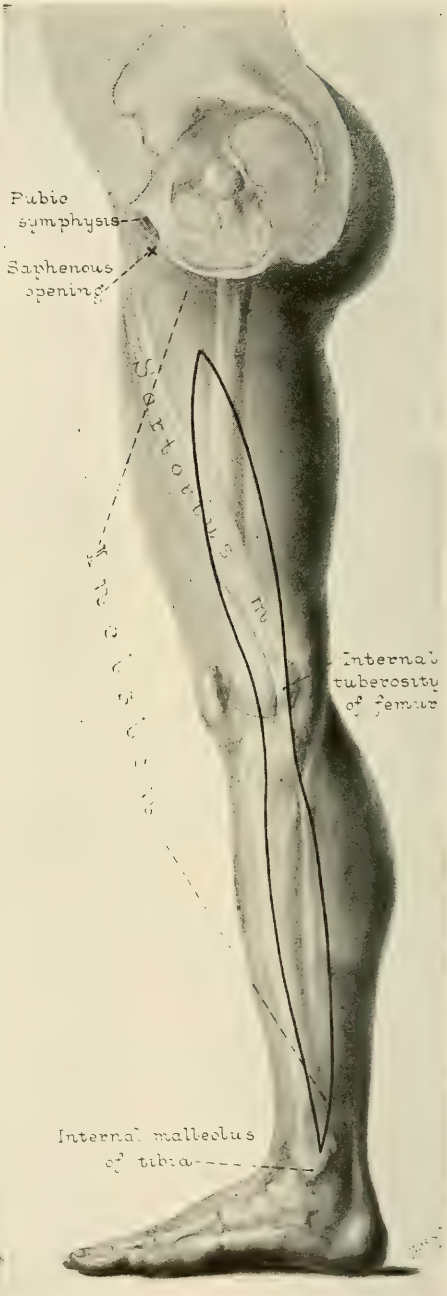

FIG. 484.—LINE OF INCISION ON THE INNER SURFACE OF THE LEG AND THIGH. (Sistrunk, in "Jour. Amer. Med. Assoc.," 1918.)

Recent operative procedures have been devised with the object of establishing a deep collateral circulation of lymph in the limb for the present relief and future prevention of lymph-stasis. A certain amount of the diseased tissue is removed at the time of operation, and rest in bed, elevation of the limb, and judicious bandaging complete the treatment. It is recognized that the aponeurosis forms a wall between the

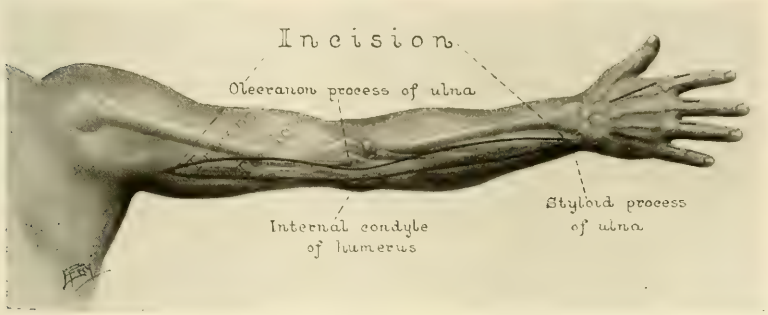

FIG. 485.—LINE OF INCISION ON THE OUTER SURFACE OF THE ARM AND FOREARM. (Sistrunk, in "Jour. Amer. Med. Assoc.," 1918.)

superficial and deep lymphatics of the extremities, and in order to secure the desired deep drainage of the superficial tissues Lanz, of Amsterdam,[3] in a case of elephantiasis of the thigh and leg of four years' duration, made a longitudinal incision the length of the external aspect of the thigh, through the diseased mass, the fascia lata, and down to the bone. Detaching the periosteum, he trephined the femur in

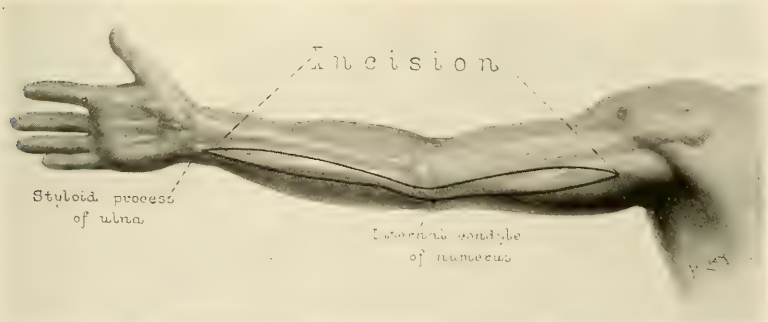

FIG. 486.—LINE OF INCISION ON THE INNER SURFACE OF THE ARM AND FOREARM. (Sistrunk, in "Jour. Amer. Med. Assoc.," 1918.)

three places and introduced into the medullary cavity partially detached strips of the fascia lata. The aponeurosis was also slit in several places by short incisions. The result was a decided success, the limbs becoming almost normal in size and function.

No succeeding surgeon has found it necessary to go to the length of trephining the bone, but the principle of deep lymph-drainage by penetrating the aponeurosis is well established. Various modifications

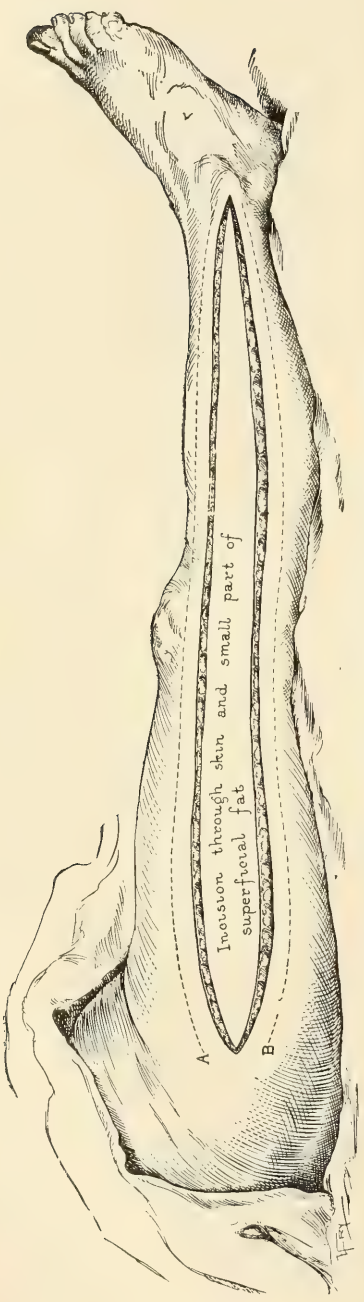

FIG. 487.—INCISION USED ON THE OUTER SURFACE OF THE THIGH AND LEG.
Dotted lines *A* and *B* show extent to which the skin is reflected for the removal of subcutaneous fat. (Sistrunk, in "Jour. Amer. Med. Assoc.," 1918.)

Flap of skin, superficial fat and aponeurosis
Line of first incision
Line of second incision
Muscles covered by thin fascia

FIG. 488.—SKIN, A LARGE AMOUNT OF SUBCUTANEOUS FAT, AND APONEUROSIS REMOVED IN ONE PIECE. (Sistrunk, in "Jour. Amer. Med. Assoc.," 1918.)

of the Lanz operation have been undertaken with considerable success,[4,5] and Kondoléon, of Athens,[6] established what may be considered the accepted method of securing deep lymph-drainage by removing wide

strips of the fascia instead of merely splitting it. The Kondoléon operation has now been performed many times in Europe and America with a very good measure of success, greatly reducing the deformity, if not entirely removing it, and preserving a useful leg in cases in which otherwise amputation would have been necessary.

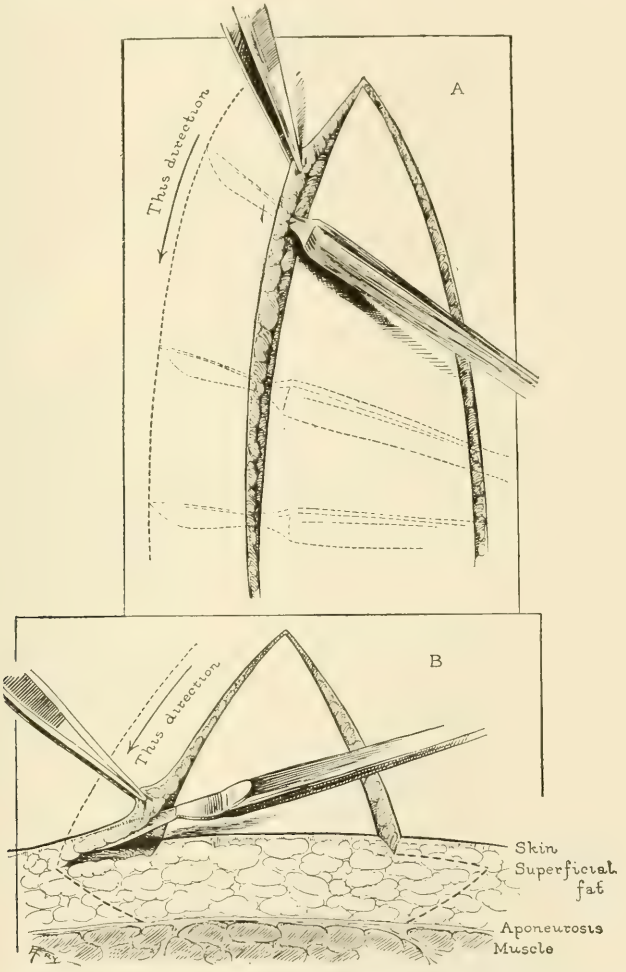

FIG. 489.—*A*, METHOD USED TO FACILITATE THE REMOVAL OF A LARGE AMOUNT OF SUBCUTANEOUS FAT. AFTER THE INCISION HAS BEEN MADE THE SKIN AND A SMALL AMOUNT OF FAT ARE REFLECTED IN ORDER THAT A LARGER AMOUNT OF FAT MAY BE REMOVED. *B*, CROSS-SECTION OF *A*. (Sistrunk, in "Jour. Amer. Med. Assoc.," 1918.)

The details of the operation, exemplified in 7 cases, is best described by Sistrunk,[7] who has perfected Kondoléon's method by removing a fair amount of skin, a considerable amount of the subcutaneous diseased tissue, and of wide strips of aponeurosis as emphasized by Kondoléon.

"A long modified elliptic incision including the skin to be sacrificed

is made in one side of the affected limb. On the outer aspect of the lower extremities this incision would extend from the trochanter to the external malleolus. Then, in order to facilitate a wide removal of subcutaneous fat, the skin is reflected on each side of the incision for a distance of about 1 or $1\frac{1}{2}$ inches. The skin is retracted and underneath each of the reflected skin edges a long incision is made through the edematous fat down to and including the aponeurosis. The incisions are made almost parallel to the original skin incision. Included between them is a quadrilateral piece of edematous fat and aponeurosis. At the upper end these two incisions through the aponeurosis are connected by a transverse incision. The tissues to be removed are now free except for the attachment of the aponeurosis to the underlying muscles.

"By traction on the tissues that are to be removed it is very easy to dissect the aponeurosis from the muscle throughout the length of the entire limb, and to remove in one long piece the skin, edematous fat, and aponeurosis. A number of vessels which tend to bleed profusely are encountered. These are temporarily constricted with forceps. After the tissue has been removed these forceps are taken off and surprisingly few of the vessels will be found to need ligatures. The wound is closed with interrupted silkworm-gut stitches, without drainage. It is necessary to do a similar operation in the opposite side of the limb. If the patient's condition permits, we usually do this as soon as the first operation has been completed; if not, after a period of eight or ten days has passed. The tissues, although diseased, heal remarkably well, and in none of the cases on which we have operated has there been the slightest infection.

"After operation the patient is kept in bed for eight or ten days. An elastic bandage is then applied and the patient allowed to get up and walk about. We have advised the use of this elastic bandage for several months, and if there is a tendency toward swelling when it is removed, it should be worn for an indefinite period. The suggestion of Matas to administer antistreptococcic serum or vaccine at intervals for some time after the operation has been followed.

"Our experience with the Kondoléon operation leads us to believe that in this we have a procedure whereby much aid can be offered to patients suffering with a true elephantiasis, and especially so to those in whom the condition is present in the lower extremities."

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CHAPTER LII

THE PLACE OF PHYSIOTHERAPY IN SURGICAL TREATMENT

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The casualties of industrial life are no less numerous than those brought about by the perverted industry of war, for in one year *750,000 workers of eighteen years are injured in the United States alone.* It has been largely because of the segregation of wounded men in hospitals and camps where treatment was given to thousands at a time that attention has been called to the importance of physiotherapy in the continuous treatment of acute and chronic surgical conditions. Out of a series of 4000 consecutive cases returned from the front to the Canadian military hospitals, some form of physiotherapy was indicated in more than one-half, while the establishment of the great Command Depots, convalescent camps, hospitals, and orthopedic centers in England made it possible to treat large bodies of men by these methods.

The men, women, and children permanently maimed on the railroad track, in the foundry, or the mill form just as grievous a tax on the community as those whose wounds were made by shell or shrapnel, and hospital after hospital is introducing or extending its department of physiotherapy to give adequate care to suitable cases, while institutions of industrial hygiene are beginning to include it in their course.

Physiotherapy includes the application of electricity in its many forms; radiant heat; water, hot and cold; massage; passive movements; muscular re-education; gymnastic exercises; and one may even add occupational therapy. Of 31,200 treatments given at the Clinic for Functional Re-education in New York in one year, electricity was used in 3400, dry heat in 7778, massage in 10,572, hydrotherapy in 2919, and muscular re-education in 6460. This proportion will naturally vary with the kind of cases and the preferences of the medical officer, for most results may be obtained by more than one method.

The conditions for which physiotherapy is especially adapted are:

1. *Injuries of the head* affecting the motor area. Neurologists have been astonished at the way in which these cases recovered in military hospitals. It is rare for an arm or leg to be totally paralyzed; the finer movements of the hand are affected before the coarser movements of the shoulder and elbow, and are slower to return. For after-treatment we must depend on re-education by simple simultaneous movements of both the sound and affected side as soon as voluntary action reappears. At first an arm or leg may be supported by a wheeled carriage (Fig. 490) or by moving it over a smooth surface (Fig. 491), or by im-

mersion in a warm bath to reduce friction to a minimum and take advantage of the slightest return of power. When the sensory cortex is injured, we find the affected area insensitive to pain, and hypotonia is present with lack of muscular sense, just as in tabes. Re-education is

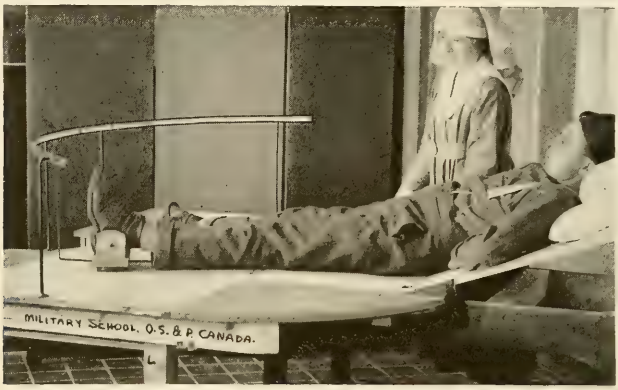

FIG. 490.—UNIVERSAL TABLE USED AS LEG ABDUCTION AND ADDUCTION PIECE. FOOT SUPPORTED ON WHEELED CARRIAGE. (Military School, O. S. and P., Canada.)

here necessary just as in locomotor ataxia, and the methods would be identical.

2. *Injuries to peripheral nerves*, all the way from bruising of a nerve trunk to its destruction and restoration by surgical means. The most skilfully performed operation on an injured nerve is doomed to failure and can accomplish little if the pre-operative and postoperative treat-

FIG. 491.—RE-EDUCATION OF THE TRICEPS. THE ARM SUPPORTED ON A SMOOTH SURFACE. (From C. Mackenzie "The Action of Muscles.")

ment is insufficient or neglected. If any tension exists after nerve suture, the arm should be fixed in greater or less flexion for about six weeks, then gradually extended. Function may be expected to be recovered anywhere from six weeks to two years, the musculospiral usually recovering quickly, the sciatic slowly. These cases are accompanied

by weakness or paralysis, muscular wasting, and contractures. They are treated by wet or dry heat to improve the local circulation, support in proper position by splints to avoid the overstretching of weakened muscles, and the resultant permanent contraction of their unimpaired antagonists, galvanic or faradic stimulation, massage to keep up or improve the nutrition, passive movement to prevent contraction, progressive active movement to restore and strengthen voluntary power, ending with gymnastic exercises and vocational training to bring back the skill that will fit the patient to take his place again in industrial life.

3. *Scar tissue,* either in preparation for or after operation. The scars of war wounds are much more formidable than those likely to be found in most civil practice. Skin, muscle, fascia, tendon, nerve, and periosteum frequently form a great confused, distorted mass, leaving the limb blue, clammy, and moist with continual perspiration, and so painful that the patient winces at the slightest touch (Fig. 492). In many cases they can be excised, but after surgical operation and in amputation stumps sensitive nerve-endings are frequently caught in the scar of the operation and are among the most troublesome conditions. Treated by the warmth of the whirlpool bath at 110° or 112° F. the cold and purple scar becomes crimson and painless and enables the masseur to stroke, knead, and move the scar or the affected joint in a way that no amount of persuasion would have made tolerable without it. The repair of scar tissue can also be hastened by the use of diathermy and ionization, and contractures caused by it can frequently be prevented or stretched by careful manipulation, if care is taken to avoid breaking down new scar tissue in course of organization.

FIG. 492.—ENTRY OF BULLET UNDER CLAVICLE IN FRONT.

Exit of bullet blew spine of scapula away. Subscapular abscess formed and was operated on. The final scar prevented the wearing of military kit.

4. *Old septic wounds* resulting in persistent sinuses can be successfully treated by physical means. Stimulation by heat and massage will frequently hasten the removal of a sequestrum that has remained a source of trouble for months, and ionization with zinc sulphate and the use of radium have an important place in the treatment of sinuses and in softening extensive scar tissue.

5. *Postoperative Conditions.*—Adhesions may be progressively stretched by elastic tension or by extension splints, or they may be broken down by forcible manipulation under an anesthetic. This may require a number of operations with fixation in the new position after

each until pain disappears. Where extension of a flexed joint is obtained by long and continuous stretching, the muscular tone must be kept up by massage and heat. The breaking down of an adhesion or gradual stretching in fibrous ankylosis restores a joint only to potential usefulness. To complete the cure a course of re-education is necessary, beginning with simple, single movements, in which the patient moves it actively throughout its entire range with power and skill, and advancing to those that are more complex. Devices for this purpose must be used until he is ready for the more complicated actions of the trade or craft he may elect to practice.

6. *Functional Neuroses.*—These take the form of palsies, contractures (coming on gradually as a rule), anesthesia, and hyperesthesia. Genuine and severe disability frequently degenerates into a functional neurosis. The change is gradual and insensible in many cases. Marked

FIG. 493.—ANKYLOSIS OF ELBOW, WRIST, AND FINGERS WITH MUSCLE WASTING DUE TO LONG CONFINEMENT IN SPLINTS.
Movement restored by treatment.

trophic changes take place, the limb becomes cold, blue and mottled, and perspires excessively, the finger-nails become brittle, and the skin glossy. Contractures must be slowly stretched and the limb kept in place by splints, for they will recur at once if the limb be left unsupported. They should be massaged and exercised by the faradic battery, and finally brought back to usefulness by a combination of hypnotism, suggestion, encouragement, and voluntary movement. The mental treatment is here even more important than the physical. Under favorable conditions from 75 to 80 per cent. of patients can be hypnotized for curative suggestion, but the operator must have determination, sympathy, patience, and the faculty of inspiring confidence. In hysteric paralysis the patient is often unconscious that he has also lost sensation, hence the use of heat and galvanism must be safeguarded. Many cases can be cured by suggestion in one sitting.

7. The repair in fractures and sprains can be greatly hastened by electric stimulation and massage, and the curse of immobilization lifted. There are many cases of permanent disability solely on account of its misuse, and recovery is always delayed. The contractures so graphically described by Volkman are nearly always caused by the misuse of splints and consequent interference with the circulation, the gradual stretching and restoration of function depending entirely on physical means (Fig. 493). A painful, sensitive joint, no matter how old the injury, should not be moved. Of course, absolute rest is here necessary, but the normal circulation and muscular tone can be retained only by electricity, light, heat, and massage.

8. Such postural defects as flat-foot, so common among hospital nurses, motormen, policemen, and others whose occupations require long hours of standing, can only be treated by changing the balance of the foot and educating the patient to maintain the restored balance by improved habits of standing and walking. Foot defects were brought into undue prominence by the military necessity for sound feet, and the fact emphasized that the question was both educational and mechanical. The bar across the sole of the boot for claw-foot, tilting the boot outward by thickening the sole and heel on their inner side; the figure-of-8 strap described by Goldthwaite for fallen arch (Fig. 494); and the strap across the metatarsal for painful spreading of the foot are all simple devices for changing the thrust of the weight and relieving the pain, so that balance may be restored and kept by muscular action, unhampered by faulty shoes.

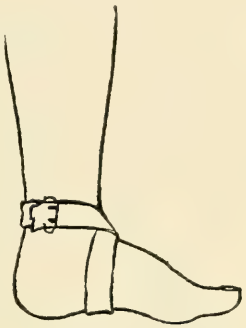

Fig. 494.—Figure-of-Eight Ankle Strap. (Goldthwaite.)

In most surgical conditions more than one form of physiotherapy is used, and the progress of treatment usually begins by preparation of the part by heat, either wet or dry, followed by massage, passive movement, and voluntary exercise, the patient graduating through gymnastics, games, and handicrafts.

MEDICAL ELECTRICITY

The object of electric treatment in surgery is:

1. To produce heat, either on the surface or in the deep tissues, and so to induce hyperemia and the absorption of inflammatory products.
2. To cause the absorption of drugs.
3. To stimulate nerves and so produce muscular contraction.
4. To sooth and alleviate pain.

The chief forms used in treatment are:

The Continuous Galvanic Current.—This current varies in its voltage, resistance, and volume according to the purpose for which it is used. Currents with high voltage and small volume, produced by arranging cells *in series*, are used for diathermy, where the resistance

of the tissues results in the production of heat. Currents of low voltage and large volume produced by arranging cells *in parallel* are used for the cautery and diagnostic lamps. The constant current of the galvanic battery which flows in one direction, and so has polarity, produces no contraction when flowing with uniform strength through the body, but if it is suddenly switched on or if it is cut off or broken, a muscular contraction is produced, and various devices are used to interrupt it so as to produce these contractions, or reverse the direction of its flow. The strength can be varied almost indefinitely by the metronome, so that the patient receives a current of constantly varying intensity, rising and falling in waves, or reversed, so that its direction is changed alter-

FIG. 495.—DEMONSTRATING APPLICATION OF IONIC TREATMENT. (From "Reconstruction," March, 1918, Military School, O. S. and P., Canada.)

nately, starting at zero, coming up to its full strength on the positive side, going back to zero, and coming back to its full strength on the negative side, thus forming a true sine curve, and called the *sinusoidal current.*

This current, rhythmic in character, is much less irritating and painful than if the circuit were opened and closed abruptly, and, in consequence, is the most popular or generally used in muscular stimulation. The irritability of the nerve and muscle through which the constant current passes is altered as follows: In the region of the *anode* irritability is decreased and muscular contraction is less readily obtained. The circulation is lowered, sensation is decreased, and pain is deadened. In the region of the cathode muscular contraction is more readily

obtained, sensation is increased, and there is hyperemia and reddening of the part.

The constant current splits salts into their constituents, the metallic portion being attracted to the cathode and the acid portion to the anode. Fatigue products, such as carbonic acid and sarcolactic acid, which result from excessive muscular activity, are thus dispersed by the cathode. This constitutes what is known as the "refreshing" action of the current, but since the anode attracts acids and repels metals, we can thus drive solutions of certain metals into the tissues by this action. The salts of lithium and copper can be driven in by the anode, and those of iodin and sodium by the cathode. This is called ionic medication.

Certain precautions must be observed before using the galvanic battery (Fig. 495). The skin of the patient should be carefully examined for abrasions. Wherever the skin is broken, the resistance is lowered and the current will concentrate on this spot, causing a burn. If possible, the area chosen for the application should be where the skin is normal. If this is impossible, the abrasions must be protected by covering them with collodion or adhesive plaster. The part should be thoroughly moistened to improve conduction. A dry or greasy skin increases the resistance. Electrodes to which the connecting wires from the battery are attached will vary with the region to be treated. They come in many sizes and shapes, and should be covered with felt, cotton, wool, or lint, the essentials being that they should be clean, soft, smooth and absorbent, and at least $\frac{1}{4}$ inch thick. Great care should be taken to have them applied to the body uniformly flat and free from creases. Burns occur at a crease because here the pressure is greater than elsewhere. The pad should also extend well beyond the metal edge of the electrode on every side. Electrodes and pads may be kept in firm position for treatment by the pressure of a well-applied bandage, by sand-bags, or other weights.

The two electrodes should not be placed close enough to touch each other, as the current would then become short-circuited instead of penetrating the tissues.

When both electrodes have been correctly applied, the current is turned on very slowly and gradually, cell after cell being brought into the circuit. The patient soon becomes conscious of a sharp, pricking sensation, and a feeling of heat. As the unpleasantness of this diminishes, the current can be increased. If the patient complains of much discomfort or burning, the current should be slowly decreased, and the electrodes remoistened and adjusted.

The region of *the cathode is the danger point.* Here burns are most likely to occur. Where anesthetic areas are treated, as in functional anesthesia, *keep a double lookout for possible burns, because the patient cannot help you, however severely he may be burnt.* Burning may be caused by too small a pad, and a good rule is to allow 1 square inch of electrode for every milliampere of current used.

At the termination of treatment the current should be turned off slowly and carefully. The *electrodes should not be removed until the*

current is completely turned off. The skin must at once be carefully dried and examined for undue redness, blisters, or burns.

When both anode and cathode are placed upon the affected part, and are of use in the treatment, the method is called bipolar galvanism. If only one is wanted and the other would be detrimental, the pole placed upon the affected part is called the active electrode, while the other pole or indifferent electrode is placed upon some remote part of the body and used merely to complete the circuit. This is called unipolar galvanism.

The method of application already described is "stabile" or stationary, because both electrodes are fixed upon the patient and kept at rest throughout the treatment.

When the active electrode, usually in the form of a roller disk or sponge, is moved up and down, or on and off the part treated, it is called "labile" or movable, and the action becomes stronger or weaker with its approach to, or recession from, the part under treatment.

The anode is used for neuritis in its various forms, neuralgia, and inflammation. The cathode is used to stimulate the circulation in old scars, Volkman's ischemic contraction, and other conditions requiring active hyperemia. They may be applied in a local bath; or, where this is unavailable, the labile method may be substituted, the body being treated area by area.

Salicylate of soda is recognized as being of use for rheumatic joint affections, lithium for gout, and salts of copper and zinc are antiseptics, while chlorin seems to possess the additional virtue of softening recently formed inflammatory tissue by the process of ionization. Salts of iodin, sodium, chlorin, and potassium are driven in by the cathode, which repels alkalis, while the salts of lithium, zinc, copper, and magnesium are driven in by the anode, which repels metals. A 1 or 2 per cent. solution of the required drug is made, and the padding which covers the active electrode is dipped into it. The amount that will be driven in depends on the strength of the current and the length of time it runs, the usual treatment lasting about twenty minutes. These drugs are put up in the form of tablets especially prepared for this purpose. The drugs most widely used are salicylate of sodium for chronic arthritis, fibrositis, myositis, and for certain forms of bursitis, rheumatism, neuritis in its various forms, especially lumbago and sciatica, and for the chronic pain so often left after injuries to joints and limbs; iodin in the form of potassium iodid, as an antiseptic; chlorin in the form of sodium chlorid for the treatment of irritable contracting scars—all these are introduced by the cathode. Zinc, in the form of sulphate or chlorid, and copper sulphate are used for suppurating sinuses, chronic ulcers, and other slow infective conditions. They are introduced by the anode through electrodes of zinc and copper respectively.

Faradism.—The second form of electricity used in treatment is faradism. The effect of the faradic current upon muscular tissue is very much like that of the normal nerve impulses. It throws it into a series of contractions synchronous with the make and break of the

current. If the interruptions are rapid enough and the current strong enough, the muscle is thrown into tetanus and rapidly exhausted.

The value of faradism depends on its power to act as an imperfect substitute to the normal nerve impulses when they are not fully conveyed to the muscle. When the nerves, through disease and degeneration, have lost all power of conducting their normal impulses, the muscles remain passive under the faradic form of electric stimulation, but if we turn on the galvanic current to the same muscle, it will sluggishly respond to the chemical stimulation of its substance. This difference in the action of the two currents on the same muscle enables us to secure the reaction of degeneration. After suture of a nerve and its regenertion, response to faradic stimulation takes place, but at first the contraction is longer in duration than normal. As recovery progresses, it slowly shortens until normal. Evidence recently obtained goes to show that degeneration following nerve section is not prevented or delayed by the application of the faradic current.

The most useful form of faradic battery up to the present time is the Bristow coil (Fig. 496). In this battery the primary and the secondary contain about the same number of layers of wire, a condenser is used to steady the current, and a thick core of soft iron is made to slide easily in the primary bobbin. The sliding of the iron core in and out by hand regulates the current by decreasing the amount as the core is withdrawn and increasing it as it is shoved in. The muscular contraction resulting is capable of perfect control, practically painless, and the operator is enabled to produce anything from a faint tremor to a full contraction of the muscle. This coil has been used with conspicuous success at the Military Hospitals in England, Canada, and the United States.

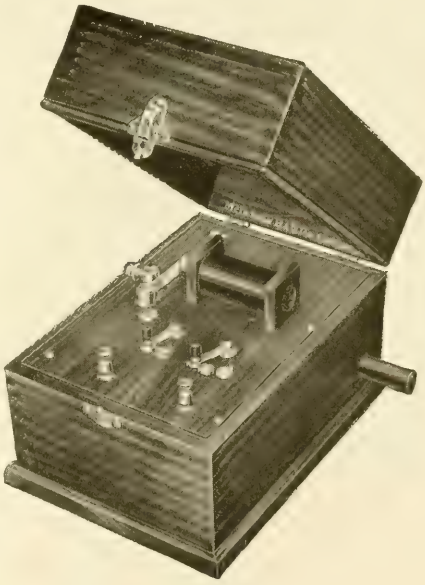

Fig. 496.—Bristow Faradic Coil.

In using the faradic battery place the indifferent electrode, a metal plate 4 or 5 inches square, covered with lint, over the nerve trunk or plexus, and the active electrode over the motor point, after wetting them both in soapy water to remove grease. The active electrode should be a metal disk about 2 inches in diameter covered with lint. Grasp the electrode, together with the muscle, between the thumb and forefinger of the left hand, and with the other hand gradually insert the core into the coil. The amount of contraction is estimated by the

feel of the muscle under the left hand. The core is inserted and withdrawn rhythmically at about one-second intervals. Fatigue, felt by weak, irregular contractions, is a signal to stop. *Great care must be taken not to produce exhaustion,* as muscles recover slowly, and may be badly damaged by overstimulation.

This surging faradism is also used to apply strong currents over large areas, the current being slowly and rhythmically increased and decreased by the metronome or rheostat. In this way a good substitute for exercise can be obtained. Bergonie has used it for exercising the abdominal muscles in obesity, and Kellogg for cases where the heart will not permit more active exercise.

The general effect of faradism is to stimulate muscle activity and to improve the local circulation.

The galvanic and faradic currents may be combined.

When part of a muscle group is responsive to galvanic stimulation only, it will be neglected if the faradic stimulation only is used. They are combined on most switchboards and on all of the combination machines known as pantostats, multostats, compostats, or universal machines.

The value of the high-frequency current and of diathermy is largely through its power to drive heat deep into parts where hyperemia is wanted, as in a knee-joint or in an area of scar tissue. The patient grasping the electrode of a high-frequency apparatus immediately feels a sense of warmth, its penetration extends to the most deep lying structure, and the resulting hyperemia makes an excellent preparation for massage.

Treatment by the *static machine* consists of (1) simple charging, which increases the blood-pressure and pulse-rate, but acts as a sedative in sleeplessness when the anode is used; (2) the Morton wave current, in which the patient is alternately charged and discharged, producing muscular contractions; (3) the brush discharge or breeze, which feels like a douche of hot sand and leaves a warm glow, useful for soothing the pain of neuralgia and neuritis; (4) single sparks given by the ball electrode, in which the effect is like a blow and followed by a reflex muscular contraction, and finally relaxation of spasm; (5) electric friction by the roller, which gives a shower of stinging sparks, producing intense cutaneous stimulation without penetration, and followed by redness of the skin.

RADIANT LIGHT AND HEAT

One of the best methods of preparing cases for further treatment is by means of radiant light and heat. If the sun's rays be passed through a prism they will be found to extend above and below the range of visibility. The infra-red rays with a low frequency of vibration give out heat and penetrate the tissues deeply. The ultraviolet, with a high-frequency of vibration, have less power of penetration and produce irritation of the skin. All artificial sources of light contain these rays in varying proportions. The arc light is rich in actinic violet rays, the incandescent lamp in heat (red) rays. A red glass screen will cut out

actinic rays, and a violet screen will diminish the heat rays, so that their proportions can be governed at will.

The electric arc light most nearly approaches sunlight, producing an effect like sunburn, and repeated treatments will tan the skin. It has a marked bactericidal action, which makes it especially useful for many skin diseases. Treatments with the solar lamp will necessarily be of short duration at first, but, like exposure to the sun, may be increased with tolerance. It is a useful counterirritant in referred pains, neuralgia, and skin infections.

The treatment of joints and structures requiring deep penetration requires more heat and fewer actinic rays, and the incandescent light is here more useful. Radiant heat dilates the capillaries, and the masseuse is thus able to work on a part already flushed with blood. The heating

Fig. 497.—Scar that Would Break Down if Soaked in Water, but Which Did Well with Dry Heat.

of a part, in all cases where the circulation is lowered, is essential before other treatment is undertaken. Scar tissue has poor circulation at best, and the toothache-like pain in it is relieved by raising the temperature and improving the local circulation alone. All weakened and impaired muscles should first be warmed before having the massage and active movements that complete their treatment.

Dry heat is to be preferred to immersion in a hot bath in cases of scars, which water renders sodden and tender (Fig. 497).

The appliances for giving heat consist of:

1. A lamp of about 150 watts, containing a reflector and attached through a handle and wire to the source of supply. This lamp is moved back and forth in circles a few inches away until the surface is reddened. Great care must be taken to keep the lamp in movement and to avoid

scorching the skin where the part is anesthetic. The treatment should never be carried to the point of extreme discomfort, and three or four minutes are usually enough, although toleration is increased by skill in moving the lamp about.

2. The local electric-light bath is composed of six to twelve 50-watt lights, contained in a reflector, so placed in relation to the part that a constant temperature can be maintained. There should be an even distribution of light and heat over the entire area, and a wide range of control from a low graduated heat continuing for fifteen to twenty minutes to the most intense heat that can be borne. The limit of temperature in these baths is about 180° F., although if ventilation is allowed and the air kept dry the temperature can go up as high as 300° F. It is especially useful in cases of myalgia and rheumatic joints, and this apparatus would be indicated for joints like the elbow, hip, and spine (Fig. 498).

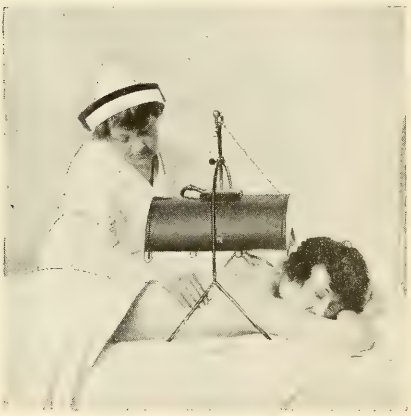

Fig. 498.—Local Light Bath. (Burdick.)

3. The full cabinet baths are of many designs and patterns, and contain forty to fifty 50-watt incandescent lights. A thermometer enables the operator to regulate the temperature, which is raised to 100° F. before the patient enters, and the current gradually increased. Cold water compresses are applied to the head, which projects out of the bath, and the patient drinks water during the treatment to promote sweating. If fainting threatens, the treatment must be stopped; and if at any time the patient feels faint, the pulse should be counted and the treatment stopped if it rises above 120. When a good perspiration has been obtained the patient leaves the cabinet, takes a warm sponge-bath, and rests between blankets for at least half an hour. The effects of these baths are: redness of the skin, a profuse perspiration, acceleration of the pulse, rise of the temperature, and increase of elimination both by the lungs and kidneys. They are of great value in all forms of intoxication, and relieve congestion of the abdominal organs.

From the beginning of time dry heat has been applied by means of hot sand and hot salt, and the hot-water bag is merely a convenient form of apparatus. Moist heat is applied by mud, poultices, and cloths or compresses wrung out of hot water. The thermophore consists of a linen pad wrung out of cold water in a container, and is merely a convenient form by which the moist heat bath can be given at any desired temperature and kept indefinitely without changing.

The chief forms of hydrotherapy are:

The **douche,** the stimulant effect of the powerful jet of water being increased by its force, which may go up to 30 pounds. A treatment

should always begin by warm water (90° F.), rising to hot (115° F.), and ending with cold (60° F.). It should not last more than one or two minutes. The greatest stimulation is from the *Scottish douche*, in which two jets, one at 100° F. and the other at 60° F., are applied alternately by a lateral sweep of the nozzle up and down the spine.

The *shower* is a gentler form of this treatment, in which the massage of the water jet is absent, but the same rules apply to it as to the douche.

Immersion baths are given at three temperatures: below, at, and above the skin temperature. The bath at 94° F., skin temperature, is soothing in character and a good sedative. Its greatest use is in decreasing nervous irritability, in whatever form it may be, and in soothing a disordered heart. The relief from the constant and insidious irritation of clothing and movement, and the support of a medium of

Fig. 499.—General Electric Light Bath for Home or Ward Use. A substitute for the cabinet bath. (Kellogg.)

about the same specific gravity as the body, doubtless accounts for much of the benefit.

The hot bath (98° to 100° F.) dilates the peripheral vessels and increases the frequency of the pulse. Its merit is founded on its stimulant effect on the circulation. The blood is drawn to the surface, which becomes red and warm. The effect is somewhat the same as the cabinet bath, without the perspiration, and it is of special use in the treatment of fatigue and also in chronic conditions in which the general circulation is sluggish. The immersion should be very brief, not more than five or ten minutes, and should be followed by a cold shower to restore the tone of the dilated vessels, and the patient should be wrapped up and put to bed for an hour.

The **whirlpool baths** have proved their value in the after-treatment

of wounds during the present war, and are now widely used. The arm or leg is thrust into a vessel containing water at a temperature varying from 105° up to 115° F. This water is circulated by means of jets set at an angle or by a propeller. Air is also introduced, so that the limb is immersed in a swirling, bubbling current (Fig. 500), and the full effect of heat is obtained in a way that is impossible if the water is still. The air-bubbles increase the stimulant effect on the skin. They are peculiarly adapted to the treatment of painful stumps, painful scars, partial paralysis, injuries to nerves, and, in fact, to any condition which lowers the circulation and nutrition of the part. They are contra-indicated in acute traumatic neuritis and osteoarthritis. The period of immersion is about twenty minutes, and with increased toleration it may be possible to raise the temperature as high as 120° F. *Great*

Fig. 500.—Whirlpool Baths. (Report of Military Orthopedic Hospital, Shepherd's Bush, London, W. 12, 1917.)

caution must be used to prevent scalding, especially if any area of anesthesia is present. It makes the best preparation for massage and manipulation in cases where the limb is cold, blue, and painful. Movements and manipulations can then be performed which would not be tolerated by the patient without this preparation, and adhesions can be stretched painlessly. The hose and nozzle can be used for regions like the spine or neck which cannot be fitted into the standard pattern of whirlpool bath. Manipulation under the continuous hot douche forms a good substitute.

The **contrast bath** is a form of gymnastics for the circulation, which is like the Scottish douche in its effect. It consists of two oblong baths, placed side by side, one supplied with water at 60° F. and the other at 110° F. The patient dips the hand or foot alternately in these baths,

leaving it in for about two minutes. They are applied to all conditions in which the local circulation requires stimulation.

The use of a glass or porcelain vessel made to contain an arm or leg permits the use of electricity and *ionic medication* through the medium of water. Water at or slightly above the skin temperature is used, and an electrode of copper or carbon is placed in the water at one end, and the indifferent electrode applied to some part of the body by a large pad. The polarity is determined unless the sinusoidal current is used, and the current turned on till a tingling sensation is felt. It is afterward increased with added toleration. Twitching of the muscles can be obtained by rhythmic interruptions of the current, and the laws governing ionization already described would apply. The entire current passes through the limb from or to the indifferent pole, and in this the unipolar local bath differs from the general electric bath.

Brine Baths.—These are ordinary tub-baths in which the patient lies immersed in hot saline solution. The amount of salt required is about 7 pounds to a bath-tubful, and the temperature ranges from 95° to 105° F., the duration twenty to thirty minutes. Joint manipulation under the water helps in cases where joints have become fixed in a faulty position and in rheumatoid arthritis. Electric treatment can also be carried out in these baths.

MASSAGE

Massage in its many forms is used to dissipate effusions after sprains, to soften and stretch contracted scars or adhesions, to prevent atrophy and contractures following nerve injuries, to hasten repair after fractures, and to improve nutrition, both local and general. In cases requiring operation scars can be loosened and softened and the operation made easier. Inflammatory action about a sequestrum can be excited and indolent ulcers stimulated. The diagnosis of lurking infection in an old wound can be confirmed, but irritation of an osteoarthritis must be carefully avoided.

Sometimes massage is of value when passive movement is contraindicated. Of the various manipulations of massage, tapotement may be effective when effleurage would be useless.

Effleurage is essentially a surface manipulation. It forms the beginning of treatment in all painful conditions, like sprains, fractures, or after breaking down adhesions. It is a preparation for more active manipulations. The hand is passed lightly over the skin, like stroking a cat, usually from the periphery toward the center. It is performed by the palm of the hand, the thumb, or the finger-tips. Both hands are used for large fleshy parts like the buttock, thigh, chest, back, or neck; the thumb or finger-trips are employed around bony parts, like the hand, ankles, wrist, forehead, and scalp, and about adherent scars; the fingers adapting themselves to the part worked upon. If properly done it should act as a sedative to pain; and when the fears of the patient have been stilled, friction may be made vigorous enough to act upon the deeper structures and wake up the sluggish circulation in and about the seat of trouble.

In **petrissage,** or kneading, the skin moves with the hand like a glove. It is done with the thumb opposed to the hand, the fingers opposed to the palm, or the two hands opposed to one another. The muscles are rolled under the hand and skin, and intermittently pressed against the underlying bone. It is slow and deep, usually following the course of the venous circulation. This manipulation should be firm, but not too painful; persistent pain following treatment means either a clumsy operator or a condition that should not be massaged. It is most useful for stretching adherent scars, in indolent ulcers, for removing the products of fatigue or effusions, and for improving the blood-supply. It is the main manipulation used in general treatment for rheumatism, fibrositis, and in the after-treatment of sprains and fractures.

Tapotement, or striking, is a surface and also a deep manipulation. It consists of slapping with the open hand, hacking with the ulnar border of the hand, using the tips of the fingers like a flail, or beating with the flat of the clenched knuckles. The blows should be sharp and quick, short and snappy, done from a loose wrist, but not heavy enough to bruise. The main action is stimulation of the superficial nerves. The vessels dilate and the part becomes reddened. If repeated long enough and strongly enough, sensation is dulled.

Vibration is a rapid form of tapotement, in which the rate of the strokes runs from 500 to 5000 to the minute, and is best performed by a machine for the purpose, with the various forms of applicators for the different regions. Vibration is followed by a feeling of numbness, then tingling, and then warmth, so that its general effect is stimulation.

The surface to be treated by massage should be scrupulously clean, and should not be greased or oiled, except occasionally about a tough or irritable scar. The part may be dusted with talcum powder and a very hairy surface may even be protected from irritation by manipulation through a silk or cotton undergarment.

A stiffened joint or painful scar should be prepared for massage in the whirlpool bath, or by exposure to radiant heat until it is thoroughly reddened. Where these are not available, it may be packed in hot sand or salt. These procedures greatly assist in making possible massage and manipulation that would otherwise be too painful.

In sprains or after breaking down adhesions, which is the same thing physiologically, massage should be given at once, beginning with effleurage and continued by kneading, alternating these two procedures until the whole region has been covered, and supporting the ankle or elbow between treatments by a bandage over cotton wool to exert elastic pressure.

After fractures the treatment by massage may begin as early as the third day, and effleurage given above and below the seat of fracture, the splints being kept in place if necessary. The technic for different fractures is fully described by Mennell, following the method of Lucas Championnière. Amputation stumps should be prepared by heat, be given effleurage, kneading, and vibration to improve nutrition and pro-

mote absorption of scar tissue; and where necessary, contractures should be stretched, followed by movement and exercise for re-education.

Red in a painful scar is the color signal of danger for the masseur who intends to stretch it. It means that there is a network of vascular loops whose thin walls are easily torn, that will bleed and form new scar tissue if roughly handled, leaving the last condition of that scar worse than its first. Treatment must begin, in such cases, with effleurage, light circular friction, and kneading of the neighboring tissue.

An innocent looking *surface scar* following a shell wound often showed a slight dimple only, deepened by any voluntary movement of the muscles, but dissection showed that it had spread out its tentacles deep into the surrounding tissue, strangling in its grasp nerves and vessels, and adhering tenaciously to bone and muscle far from its apparent place. These scars are much less frequent in civil life, but persistent pain following treatment always means too much force. Some patients wince on the slightest touch, and this false pain must be distinguished from the real and persistent variety. Slowly and gradually increase the pressure or tension, and at the same time distract the patient's attention. This will frequently serve to make the diagnosis clear.

PASSIVE MOVEMENT

Passive movement is used to stretch contracted scars, to increase the range of movement in stiffened joints, to rehearse the movements of

Fig. 501.—Stretching of Right Side.

joints whose muscles are paralyzed or weakened, and thus detect or prevent contractures. It does not always accompany massage, and may be contraindicated, as in fractures or imperfectly healed wounds. The dropped foot may have to be kept dorsiflexed, the dropped wrist extended, and the arm with deltoid paralysis abducted on a splint to keep the weak muscles relaxed and free from strain between treatments.

All movements should be done by slow, insistent pressure; quick or jerky motions frighten the patient, and he instinctively locks the joints to resist the attack. Distract his attention from the movement that is being given, especially in functional cases. It greatly assists in getting a fuller range of movement, and suggestion, deception, encouragement,

scolding, or even bullying, all have their uses in such cases. Slight adhesions can thus be broken down with great relief, especially if the part has been well prepared by heat, but serious or firm old adhesions should be left alone or broken down by the surgeon under an anesthetic. After operation for the breaking down of adhesions passive movement should be started the following day, and the joint moved once only through its range and put up in another position. This should be repeated daily and the limb kept at rest between treatments. This condition is like a fresh sprain, and must be given a chance to become quiet, but not fixed. In all cases of scars and contractures in which pain persists for twelve hours after treatment, rest the joint and fix it in the best possible position, if necessary by a splint, until the pain has disappeared, then start with massage only, without movement, given after adequate preparation by heat. An old white scar can be stretched only by continuous tension, best given by the use of splints, which should be worn for weeks or even months, and even then the added movement is acquired mostly by stretching the sound tissue that surrounds it.

Passive movement of single fingers is done best by the operator's hand, the joint being slowly extended and flexed as far as possible, and the improvement maintained by a splint worn between treatments if necessary. This is especially true of functional contractures where fixation in the correct position is essential until the patient can be taught to maintain the correct position himself. Fingers should be flexed with the wrist in extension and extended with the wrist in flexion.

The wrist is flexed, extended, adducted, and abducted by the operator's hand passively as follows: The patient's fist should be clenched and grasped by one hand, the other being used to steady his forearm. The movement should be strong, firm, and slow.

Pronation and supination may be done passively by the hand of the operator, seated facing him and grasping the patient's hand, palm to palm, the patient's arm and forearm being kept at right angles, and so fixed as to prevent rotation of the shoulder. It is like the old game of twisting wrists.

Flexion and extension are performed by the same grasp of the hand, and from the same position.

Rotation of the shoulder is performed by the operator as follows: The patient sits with the arm down, the forearm flexed at a right angle. The operator, standing behind him, grasps the wrist and forearm with one hand, and the shoulder with the other. The elbow is the fixed point, and the wrist is used as a lever, being brought out and in slowly without changing the angle of flexion at the elbow.

Circumduction is performed by seating the patient on a stool, the arm stretched straight out horizontally from the side, the operator standing behind with one foot on the bench, and the knee under the axilla to steady the shoulder, which is also held by one hand, while with the other he circumducts the shoulder by grasping the arm just below the elbow. Slight adhesions may be broken down by these means not only without injury, but with great relief to the joint, but any per-

sistent pain after treatment warns the operator of the necessity for caution.

Circumduction of the ankle is done by the hand, but full flexion is difficult or impossible when the powerful tendon of Achilles is contacted, and a preliminary tenotomy is often indicated (Fig. 502).

Flat-foot and claw-foot (pes cavus) are often treated for long periods by massage and passive movement without results. These procedures can have but a minor place in the treatment of such conditions, and they must depend on surgical or orthopedic treatment by operation, support, and re-education.

Flexion and extension at the knee may be done by the hand, the patient being seated with the leg over the end of the plint for flexion, or lying prone on the plint for either extreme flexion or full extension. The hand is much better than any machine, because it can give the important rotation movement of the leg upon the thigh in flexion, so well

FIG. 502.—PASSIVE FLEXION OF ANKLE-JOINT BY MANIPULATION. (McKenzie "Reclaiming the Maimed.")

insisted upon by Sir Robert Jones. At the end of each complete flexion of the knee twist it in and out.

The hip can be extended, flexed, rotated, adducted, and abducted, with the patient supine on the plint, the ankle of the side to be moved being grasped by the operator by one hand, his other hand placed on the knee of the same leg, and the other knee drawn up to a right angle. The hips should be strapped in place. The movement of the thigh can then be made in the required direction.

Passive movement of the back can best be done with the patient strapped at the level of the trochanters, prone to a plint, with the body projecting over the end, and supported by an assistant (leg lying); the trunk can then be flexed, extended, or rotated on the fixed pelvis. Rotation can also be given from the position of sitting astride the plint by pressure on one shoulder and tension on the other.

Passive movement of the neck in all directions should be done by the hands only and with the greatest caution, the patient either sitting up or lying supine on the plint with the head projecting over the end.

MECHANOTHERAPY

There are three methods by which lost or impaired movements are brought back:

1. Specially designed apparatus for exercising specific groups.

2. Gymnastic movements and exercises designed to train definite movements and co-ordinations.

3. Handicrafts, in which the muscles are unconsciously used for the purpose of accomplishing some useful work. Each of these, instead of being antagonistic, is a link in the chain of a complete treatment.

The most widely known system of mechanotherapy before the war was that of Zander, but during the last five years it has fallen into general neglect, partly on account of the great cost of an installation and the complicated construction of the machines, partly from the real danger in employing an apparatus for stretching contractions which is driven by power beyond the control of the patient, and, lastly, from the intolerable boredom that results from the mechanical repetition of a single movement without producing any apparent result.

More simple and inexpensive appliances have been devised during the war as a substitute to bring into more general use this valuable form of treatment, and these appliances have been used and tested in the many hospitals and convalescent camps in France, England, India, Canada, at the hospital of the Navy Yard, Brooklyn, and at the Clinic for Functional Re-education in New York. Just as the neglect of medical electricity is due largely to lack of knowledge of its technic, so ignorance sometimes accompanied by an unwillingness to investigate the subject is responsible for the small place occupied by mechanotherapy in most hospitals.

The exact place of mechanotherapy must always be kept in mind. That place is immediately after the patient has been prepared by heat, electricity, massage, and manipulation, and it comes before the more complicated and less regulated movements of a craft. It is more closely allied with surgical treatment than it is with occupation, and to be successful it requires an accurate knowledge of the anatomy of the parts involved. A patient will consciously or unconsciously favor a weak muscle group by using other and stronger groups, where possible, to disguise this weakness, so that an apparent action is often shown where the muscles are really impotent. With a little practice a man whose quadriceps is paralyzed can throw his leg forward, lock his knee, and walk somewhat as if the extensors were really in action. This is also true of many movements of the shoulder, arm, and hand. It is necessary, then, to determine with great care whether or not an action is absent or impaired and to prescribe exercises that will bear directly upon it without carrying an analysis to such a point that the apparatus and technic becomes too complicated for practical use.

The appliances here described, though far from complete, are designed:

1. To isolate the muscle groups that most frequently require to be developed.

2. To give resistance to the movement by a graduated load.

3. To give an easy method of measuring the range of movement, and the amount of work done.

4. To arouse and hold the patient's interest by such devices as the tripping and running down of a weight when it reaches a certain height, the click of a ratchet, or the moving of an indicator over a graduated scale.

The psychology of this is not new. It is the same as that used by the proprieter of a machine familar to every frequenter of the country fair. You hit a post with a mallet, and a pointer runs up an indicator. If it reaches the top, it rings a bell, and sometimes you get your money back. No man of ambition can resist it, and so in these appliances where the weight is raised, trips, and runs down, the patient can compete against his own record as seen by his own eyes, or against the records of others having similar disabilities, and his interest in the game is thus stimulated from day to day.

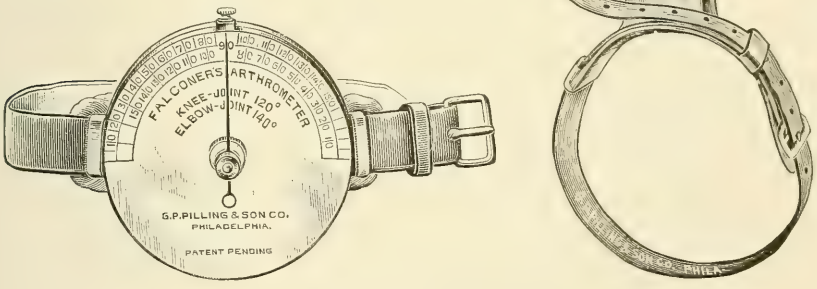

FIG. 503.—FALCONER ARTHROMETER.

Some of the appliances are made for the purpose of passive stretching, but they differ from the Zander machines in that they are always under control of the patient. He may be safely trusted to desist from stretching firm adhesions long before there is danger of rupturing them. If they ought to be broken down by force, this operation should be done by the surgeon, after due consideration. Most of the appliances have protractors attached, so that the patient can see the range of movement in his impaired joint, in degrees, and this gives him an additional incentive to use his best efforts. The measurement of ability to repeat movement is in terms of weight raised and number of contractions.

The masseuse should try to interest the patient in watching the range of each movement, as shown on the scale, or by counting the clicks of the ratchet, in watching the rising weight as it is lifted, and in calculating the total amount of work done in foot pounds, and in following his record of improvement.

Of the many methods used, and instruments designed to measure the extent of movement in an impaired joint, the best and simplest I have seen is Falconer's arthrometer, readily adjusted to any movement re-

quiring measurement (Fig. 503). Such a record should be taken at the beginning and from time to time throughout treatment. The maximum strength of the grip can be taken conveniently by partly inflating the cuff of a Tycos sphygmomanometer, and noting the height to which the mercury is raised when the cuff is squeezed. This is quite as reliable as the expensive and complicated bulb devised by Amar for a similar purpose, and records the slightest change in power of a weak hand.

During the war Dr. E. A. Bott designed a series of appliances for military hospital work in Canada, in which the resistance was supplied

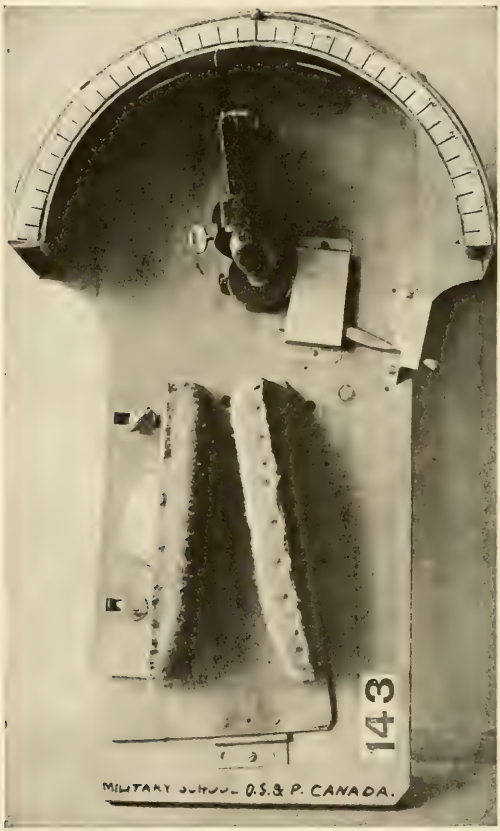

Fig. 504.—A. E. Botts' Apparatus for Wrist Flexion and Extension Showing Friction Brake. (Military School, O. S. and P., Canada.)

by a friction brake, the amount of friction being measured on a scale. This replaced the principle of the weight and pulley and was ingeniously applied to nearly all the joint movements (Fig. 504).

Upper Extremity.—1. **Finger Board.**—(*a*) For stretching contraction of the fingers, in flexion, and (*b*) for stretching abduction at the metacarpophalangeal joints (Fig. 505).

(*a*) *Extension of Single Fingers.*—The fingers are placed on the board in moderate flexion, and the finger under treatment goes up the

stair, step by step. Note the last step at which the finger under treatment can be raised from the step without assistance. Depress the hand to stretch still farther.

Fig. 505.—Finger Board for Stretching Abduction of Fingers. (Military School, O. S. and P., Canada.)

(*b*) Place the index-finger against the peg at 1 and spread the second finger out, noting the farthest point at which it can touch the peg. Repeat with the second, third, or fourth.

Repeat each movement not more than five times.

2. **Finger Pulleys.**—For flexion and extension of the fingers. Strap the wrist to the arm-rest, insert the fingers into the chamois leather

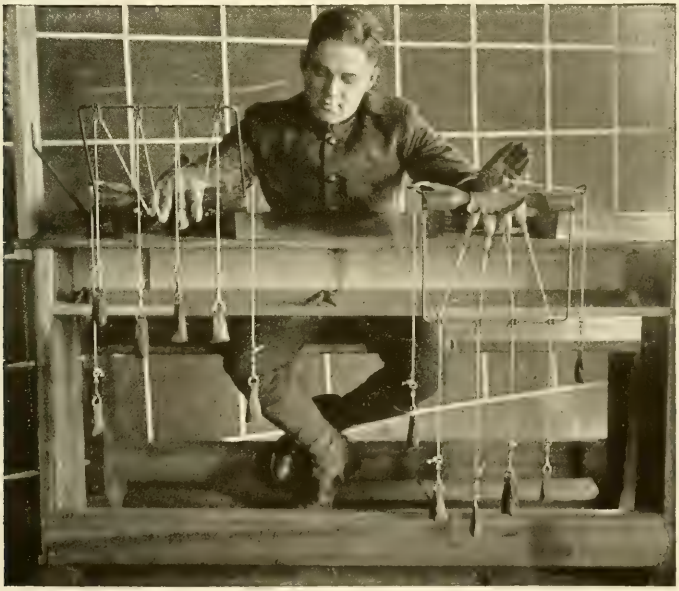

Fig. 506.—Pulley Weights for Exercising Fingers in Flexion and Extension, Right Hand Doing Exercise 1; Left Hand with Thumb Attachment Doing Abduction. (From McKenzie, "Reclaiming the Maimed.")

glove stools, and fix them there by tight elastic bands. Add weights until they can barely be lifted by the voluntary power of each finger. The weights are increased as improvement goes on, and the movements are repeated up to the point of exhaustion (Fig. 506).

First Exercise.—High attachment. Flex the metacarpophalangeal joints, keeping the interphalangeals rigidly extended (Fig. 507).

Second Exercise.—Horizontal attachment. Flex the interphalangeal joints, keeping the metacarpophalangeal joints extended (Fig. 508).

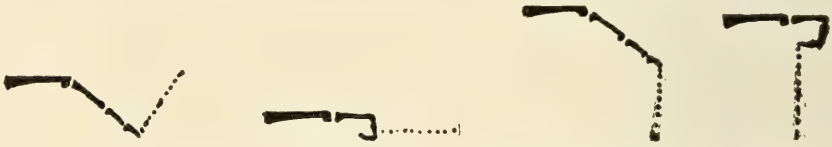

Fig. 507. Fig. 508. Fig. 509. Fig. 510.

Figs. 507–510.—(From McKenzie, "Reclaiming the Maimed.")

Third Exercise.—Low attachment. Extend the metacarpophalangeal joints, keeping the interphalangeals extended (Fig. 509).

Fourth Exercise.—Low attachment. Extend the metacarpophalangeal and flex the interphalangeal joints (Fig. 510).

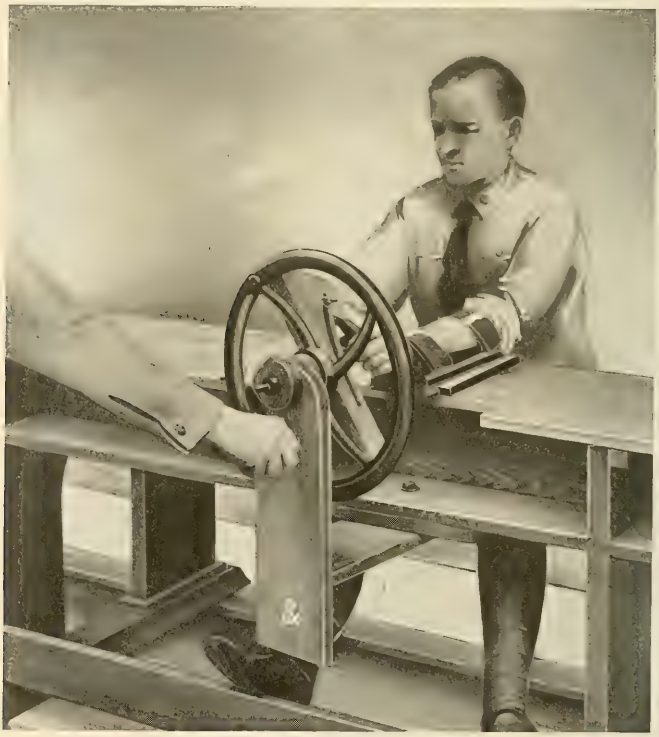

Fig. 511.—Wrist Circumduction.

The operator, seated opposite the patient, should count the repetitions and encourage his efforts. Each exercise to be continued till movement shows flagging, and then stopped. The most convenient weights are shot-bags of heavy canvas, loaded to 2 ounces each, and attached by hooks.

3. **Thumb Adduction and Abduction.**—Hand in pronation. Attach the thumb stool on the radial side to the thumb for adduction.

First Exercise.—Draw the thumb across the hand. Repeat the movement to exhaustion.

Second Exercise.—Attach the stool on the ulnar side to the thumb; draw the thumb out in abduction (Fig. 506). Repeat to exhaustion.

4. **Finger Treadmill.**—For voluntary flexion of fingers. Strap the wrist and turn the wheel by flexing the fingers in turn till the weight trips and runs down. Repeat. The amount of work done by a single

FIG. 512.—WRIST ADDUCTION.

finger can be calculated by using that finger only, and noting distance or the number of times the weight is raised.

5. **Circumduction of Wrist for Voluntary Movement and for Stretching.**—Strap both the wrist and forearm, grasp the handle, and turn the wheel about twenty revolutions each way (Fig. 511). Move out the attachment to the farthest possible point compatible with the movement. The operator may assist at the most difficult part of the turn by turning the crank and so stretch a limited action.

6. **Adduction and Abduction of Wrist.**—Place the fingers under the straps on the hand board, strap down the wrist and forearm, and adduct the hand, noting the range of movements on the protractor. Reverse

the ratchet for abduction (Fig. 512). The weights will vary for these two movements, which should be done separately. Where there is little or no grasping power, flexion and extension of the wrist can be exercised by clamping the hand between two upright plates (Fig. 513) attached to the handpiece, and flexing or extending against resistance. When grasping power is present the next appliance should be used.

7. **Flexion and Extension of Wrist.**—(1) Grasp the roller overhand and wind up the weight without releasing the grasp and exerting the full range of movement (Fig. 513). The larger section is grasped when

Fig. 513.—Wrist Flexion.

the grip is weak and the smaller as the power in the hand increases. The scale will measure the range of the joint, and the weight and distance multiplied gives the total work done in foot pounds. Precaution: See that the movement is done at the wrist only, and not at the elbow or shoulder. (2) Reverse the grasp and repeat for flexion.

8. **Pronation and Supination.**—The patient stands facing the machine and grasps the handle with the left hand, his left elbow-joint flexed, his right forearm across his back, and his hand grasping his left arm above the elbow to prevent sideward movement. Set weight and

ratchet for supination with the pointer perpendicular. The grasp should not be released and at each turn into supination the clicks should be counted, and the angle of movement noted on the protractor until the weight trips and runs down. See that the patient does not move his elbow out or in or twist his body. Reverse the ratchet and repeat for pronation.

The ordinary pully weight of the gymnasium is the most convenient for some movements.

9. **Flexion and Extension at Elbow.**—(1) The patient faces the pulley weight, grasping the floor handle, the arm and cord in line. Flex and

Fig. 514. Fig. 515. Fig. 516. Fig. 517. Fig. 518.

Figs. 514–518.—(McKenzie, "Reclaiming the Maimed.")

relax the forearm (Fig. 514). (2) Patient faces away from the machine, grasping the shoulder handle, the arm full flexed, the upper arm in line with the cord. Extend and relax the forearm (Fig. 515). In each of these exercises the position of the upper arm must remain unchanged. If this is not done, the direction of the pull is changed.

10. **Shoulder Rotation.**—Grasp the floor handle, the elbow on a bracket, shoulder high, the forearm flexed to a right angle. Pull up with his hand throughout the whole range of the shoulder movement without changing the height of the elbow or its angle of flexion (Fig. 516).

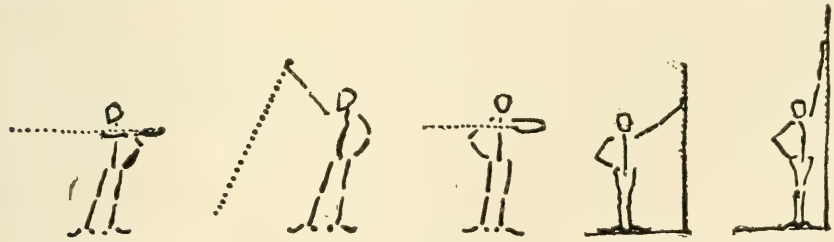

Fig. 519. Fig. 520. Fig. 521. Fig. 522. Fig. 523.

Figs. 519–523.—(McKenzie, "Reclaiming the Maimed.")

11. **Flexion and Extension of the Shoulder-joint.**—(1) The patient stands with his back to the floor handle, the arm down and straight. Arm forward, raise and lower (Fig. 517). (2) Face to the floor handle, draw the arm back, and lower to position (Fig. 518).

12. **Adduction and Abduction of the Shoulder.**—The patient stands with the side to the pulley weight, shoulder attachment, arm and cord in line. (1) Bring the arm forward across the chest (Fig. 519). (2) Patient stands as in Exercise 1, but using the floor attachment. Bring the straight arm upward and lower to position (Fig. 520). (3) The

patient stands with the side from the machine, grasping the shoulder attachment. Extend the forearm and arm, keeping them at the shoulder level (Fig. 521).

13. **Passive Abduction of Shoulder.**—Patient standing, with the side to the creeping board and the forearm rigidly extended. Climb up the board by the fingers with a straight arm, and note: 1st, the highest point at which the fingers can be lifted from the board by the patient (Fig. 522); 2d, the level to which he can bring up his arm without bending his elbow (Fig. 523). Keep the body rigid throughout, not bent or twisted.

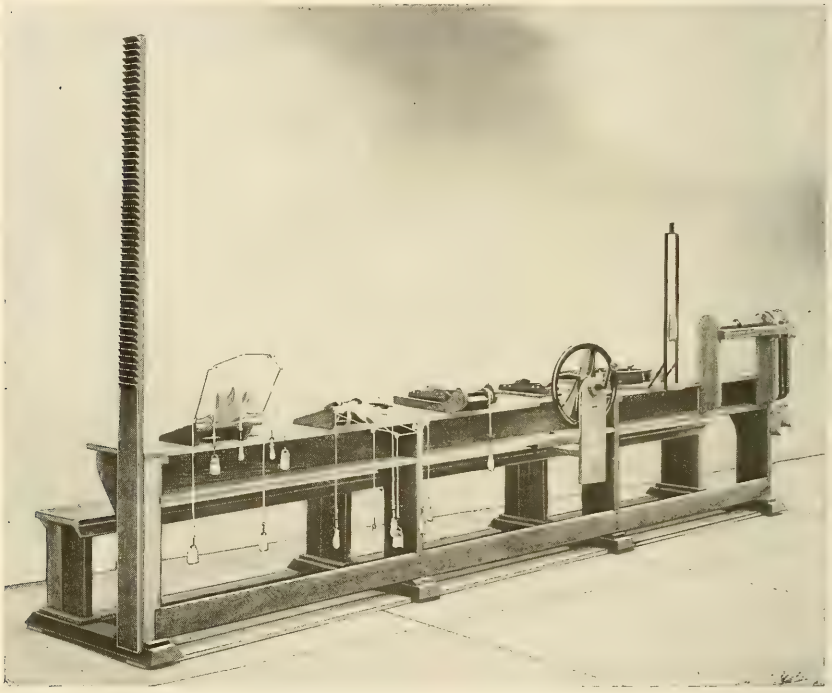

Fig. 524.—Arm Table, Showing, From Left to Right, Creeping Board Finger Pulleys, Treadmill, Wrist Circumductor, Abductor, and Adductor, Wrist Roll for Flexion and Extension, and Pronation and Supination of the Forearm. (McKenzie.)

With the exception of the pulley weight these appliances can all be mounted on one table with bench attached (Fig. 524).

General movements that are of value in treating the muscles of the upper extremity are rolling up a ball of paper with one hand, throwing and catching balls of all sizes and weights, quoits, swimming, bowling, pingpong, crokinole, billiards, weaving, knitting, rope splicing, knots, the use of tools, like scissors, boring, hammering, modeling, painting, bookbinding, saddlery, and shoemaking.

Lower Extremity.—14. **Circumduction of the Ankle.**—The patient sits with his foot strapped in place. The range of movement is regulated by a thumb-screw on the crank (Fig. 525). The handle is

turned by the patient or operator, for this is a stretching movement which should precede the voluntary active movements of the ankle.

15. **Inversion and Eversion of the Foot.**—(*a*) The patient walks on the inversion ridge a definite distance with hand-rail support (Fig. 534, R. the M.). (*b*) Ditto for eversion. Both (*a*) and (*b*) are stretching movements, and should precede (*c*), which is active. (*c*) The patient is seated or stands with the foot and leg strapped to the apparatus. Evert the foot against the weight on the cord, and note the range of the movement on the protractor and the total weight raised (Fig. 526). Reverse this ratchet and repeat for inversion.

16. **Dorsiflexion of Ankle.**—The patient sits or stands with his foot strapped to the foot-piece. Flex the ankle, raising the weight (Fig. 527).

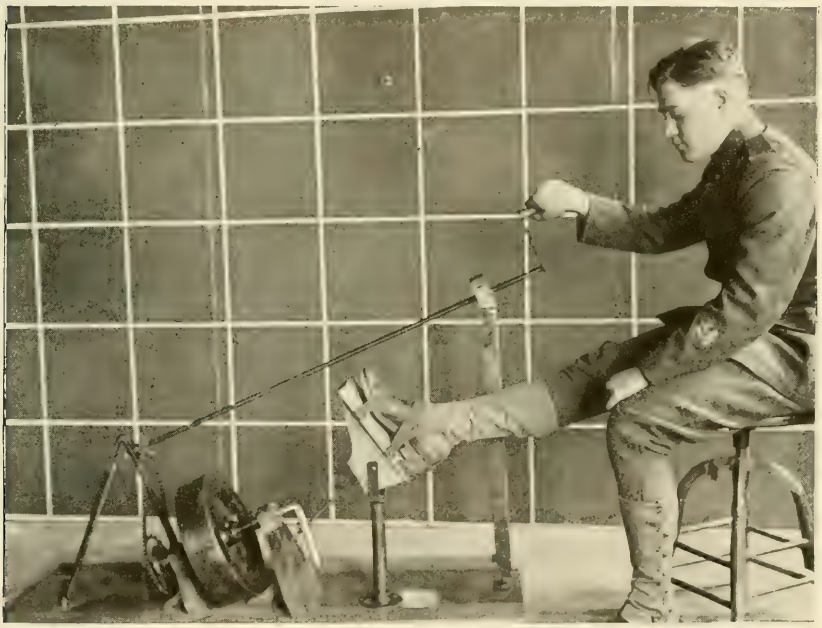

Fig. 525.—Circumduction of the Ankle. A Stretching Movement Under the Patient's Control. (McKenzie, "Reclaiming the Maimed.")

The extent of the movement may be estimated by the number of clicks, the exact measurement noted on the protractor, and the total amount of work done is easily calculated.

17. **Rotation of the Knee.**—(*a*) The patient is seated with the foot strapped to the foot-piece and the leg against the brace. He adducts or abducts the foot, rotating the knee, the extent of each movement being marked on the protractor. (*b*) The patient stands with the knee locked in extension and ad- or ab-ducts the foot. This movement measures hip rotation if care be taken to keep the pelvis fixed. In both the foregoing positions the lateral movement of the flexed ankle is slight.

18. **Knee Flexion and Extension.**—Pulley weight machine. Exercise 1. Face to the machine, strap the foot to the floor attachment.

Movement: Flex the knee against resistance (Fig. 528). Exercise 2. Face from the machine, strap the foot to the floor attachment, the

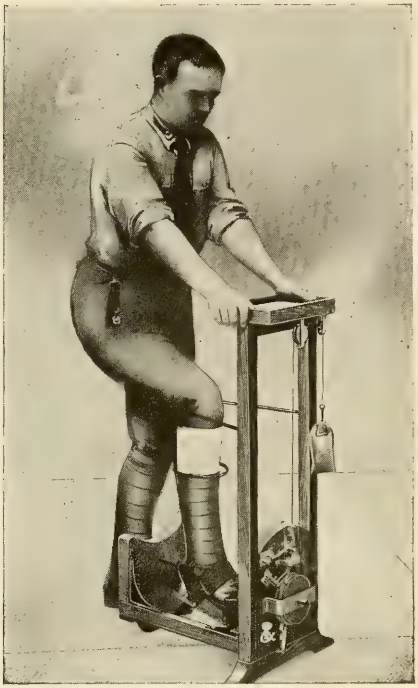

FIG. 526.—FOOT EVERSION.

FIG. 527.—ANKLE DORSIFLEXION FOR FOOT-DROP.

flexed leg and the cord in the same line. Movement: Extend the knee against resistance (Fig. 529).

19. **Hip Adduction and Abduction.**—Pulley weight. Exercise 1. Side to the machine, the foot strapped to the floor attachment. Move-

FIG. 528.

FIG. 529.

FIG. 530.

FIG. 531.

FIG. 532.

FIG. 533.

FIGS. 528–533.—(From McKenzie, "Reclaiming the Maimed.")

ment: Adduct the thigh, keeping the knee straight (Fig. 530). Exercise 2. Side from the machine, foot strapped to the floor attachment. Movement: Adduct the thigh, keeping the knee straight (Fig. 531).

20. **Hip Flexion and Extension.**—Exercise 1. Face to the machine, foot strapped to the floor attachment. Movement: Extend the thigh with the leg stretched (Fig. 532). Exercise 2. Face from the machine, foot strapped to the floor attachment. Movement: Flex the thigh, keeping the knee straight (Fig. 533).

21. **Thigh Flexion, Knee Flexion, Foot Dorsiflexion.**—Patient steps through the rungs of a horizontal ladder with parallel bar arm rests (Fig. 534). The ladder is made adjustable for height at one end, and raised to increase the movement required to lift the foot over each rung. This is especially useful for leg amputation cases to give strength and control of the stump.

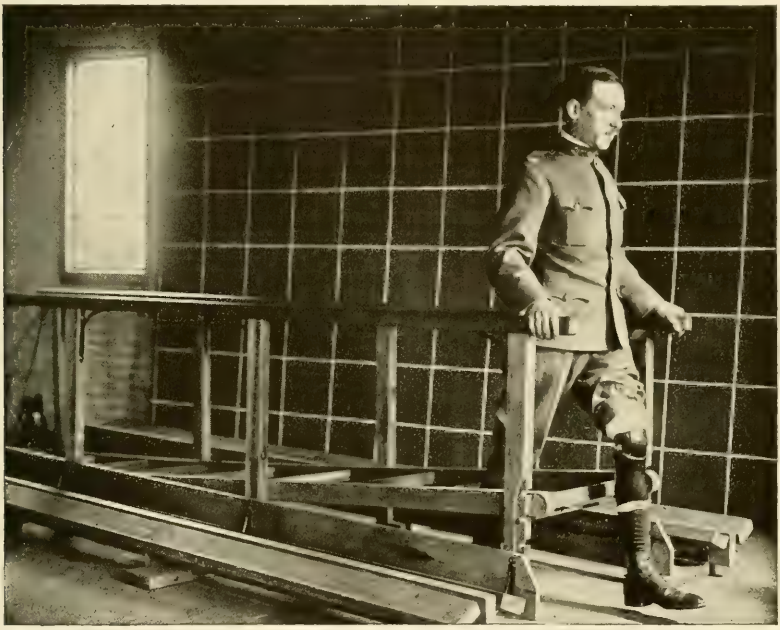

Fig. 534.—Amputated Case Practising Walking Through the Ladder to Exercise the Stump and Teach Control.
Inversion and eversion treads also shown at the sides. (From McKenzie, "Reclaiming the Maimed.")

22. **Thigh Extension, Knee Extension, Foot Plantar Flexion.**—The bicycle trainer with an increasing load of distance or friction (Fig. 535).

General Exercises.—Walking, hill climbing, dancing, kicking a football, or hockey puck, balancing, skipping, swimming, and rowing with a sliding seat.

In the treatment of stumps a sheath should be attached and the various pulley weight movements carried out as if the limb were intact (Fig. 536).

Amputations.—The re-education of leg amputation cases begins with the preparation of the stump, the fitting of the artificial limb for comfort, and for the correct bearing of the weight. The patient should first learn to balance, which may be made safe if he be suspended by a belt

FIG. 535.—THE BICYCLE IS ARRANGED WITH ADJUSTABLE PEDALS AND RESISTANCE. It can also have motor for passive movement. (Military School, O. S. and P., Canada. McKenzie, "Reclaiming the Maimed.")

FIG. 536.—STUMP EXERCISES. (Military School, O. S. and P., Canada.)

under the arms, working from an overhead trolley or by grasping a bar or pair of parallel bars (Fig. 535). This inspires confidence, and prevents falls, especially after amputation at the thigh, where the balance is very difficult to get. The patient then progresses to the use of sticks and progression on a smooth surface. He should discard crutches from the first. This is very important. He then learns to walk on a smooth, level surface with one stick only, to clear obstacles, like the ladder rungs already described, and finally to walk through soft sand, on uneven ground, up and down inclines, and over obstructions.

CORRECTIVE GYMNASTICS

Valuable as these appliances undoubtedly are, the re-education of lost or impaired function must be obtained as soon as possible from movements in which the joint unconsciously performs the required movement in a gymnastic exercise, game, or a handicraft.

There is a certain introspection in all movements that are purely therapeutic in character, and this pill must be sugared by a coating of recreation or utility as soon as possible.

In corrective gymnastics two things must be kept in mind: 1. The patient should perform the exercise with the sound limb as well as with the limb that is crippled in order to be sure that the exact movement required is actually understood. For this purpose it is advisable, when possible, to have movements performed simultaneously with both arms when the object is to re-educate the one arm only.

2. The patient's attention should be distracted as much as possible from the region that is under treatment. If a stiff shoulder is to be stretched, it may be advisable to have him stand and grasp with both hands a fixed bar, and then to squat to the full knee-bending position. In this way the shoulder is stretched, but the patient's attention is directed toward the leg movement.

Exercises should be combined in the form of prescriptions, and in hospitals where similar cases are segregated patients may be taken in classes up to 8 or 10 for similar conditions. During the war the stiff wrist- and finger-joints following prolonged and improper use of splints were frequently treated by having the patient use the punching-bag, the affected hand being encased in a special glove which bent the fingers and strapped them down in their positions. In the excitement of the exercise adhesions were stretched that could not have been done in cold blood. The throwing, catching, and kicking of balls is most valuable in many such cases.

In that condition known as "internal derangement of the knee," whether due to misplaced cartilages or hypertrophied synovial fringes, treatment should start either before or after operation by flexion and extension of the leg. From this proceed to the use of the sliding seat in sculling and the bicycle, and so to free exercises without apparatus. Wasted muscles above the joint are thus brought back to their normal condition, and the tendency to recurrence greatly lessened.

In surgical conditions involving the chest wall exercises are valuable

to prevent adhesions of the pleura, to restore a collapsed lung, and to restore the normal shape of the chest wall by the inflation of the lung. Such a prescription would include lower costal breathing, abdominal

Fig. 537.—Training in Use of Stumps. (Military School, O. S. and P., Canada.)

breathing, side bending movements for stretching purposes, artificial respiration after Sylvester's method, pulling up on the arm of the injured side (Fig. 501, E. in E. and M.), and pressing in as the arm is

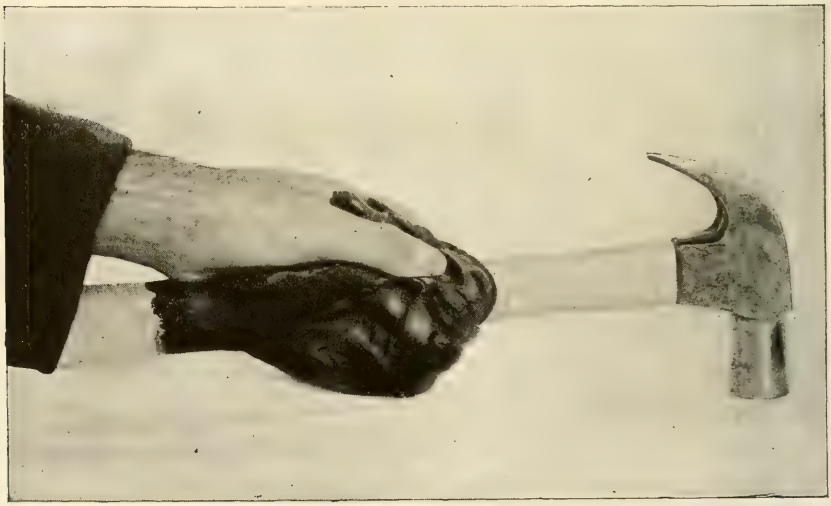

Fig. 538.—A Hammer Handle Made to Fit a Deformed Hand. It is First Surrounded with Dental Wax Softened in Hot Water, Then Patient Grasps it as Tightly as Possible, Making an Impression of the Deformed Hand. Wax is Then Hardened by Dipping in Cold Water. Patient Now Has a Handle Shaped to His Hand. As Flexion Develops in Fingers New Impressions Are Made. (Allen.)

lowered, in this way giving extra movement to the affected side, care being taken always that no violent stretching exercise is given until at least five weeks after the wound is completely healed.

In every well-organized hospital provision should be made for treat-

FIG. 539.—USE OF THE "SALARG HOOK" IN LIGHT AND HEAVY WORK. (Military School, U. S. and P., Canada.)

ment by means of corrective exercises, and also through recreation. This is especially true in children's hospitals and those requiring super-

vision for months or years (Fig. 537). This will be followed or accompanied by occupations in the ward or in special classes such as have been employed with such success in military hospitals.

Occupational therapy, or curative manual treatment, consisting of light and congenial occupation in some handicraft, has a most valuable place in a course of treatment. The child who is undergoing treatment for hip disease must remain for months in the hospital. During this time his education should not be neglected, and provision should be made for the carrying on of ordinary school work as well as the teaching of some trade or craft. The man who has been disabled and requires a long period of treatment here has the opportunity of acquiring a new trade or craft and of being saved from "hospitalization."

Occupational therapy should be begun very early in treatment in order to carry on the improvement in muscular strength and control obtained by treatment. It should give him an education along the lines that he has already worked and it should have a sufficient moral effect on him to improve and encourage that self-respect that will make him want to stand on his own feet and not be dependent on charity.

It is of little moment whether a man develops the muscles of his arm by the use of a saw, or whether he wishes to make a box and incidentally uses his arm for the purpose of sawing, the physical work is done in both cases, and the muscular development obtained. Tools can be modified for his use if necessary (Fig. 538, Mock). The application of this work to the civilian hospital is necessarily more difficult than in the military hospital. At the great orthopedic hospital at Shepherd's Bush, London, men who took regular work had special privileges granted them which were denied those who would not. In consequence there were very few who did not take advantage of the splendidly organized workshops that formed so interesting a department of this hospital, but the principle is the same, whether the man has been injured in the factory or in the trenches.

This treatment by occupation cannot in any way be taken as a complete substitute for the more accurate treatment by mechanotherapy and gymnastics. It differs from these, however, in that the remedy is given in increasing doses as a patient improves, and the effect upon the morale and the mental attitude of the patient is the best possible preparation for his taking up again the duties of active life after a long residence in the hospital.

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CHAPTER LIII

DIAGNOSTIC IMMUNOLOGIC REACTIONS AND SPECIFIC THERAPY IN SURGICAL DISEASES

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Philadelphia

The subject of immunity bears a particular relation to those surgical diseases caused by bacteria and animal parasites; space does not permit a discussion of what is known of the natural defenses against diseases of surgical interest nor of the mechanisms involved in resistance to the activities of microparasites when infection has occurred, but particular emphasis is placed upon what may be termed the more practical aspects of immunity in relation to surgery, namely, a consideration of certain diagnostic immunologic tests and reactions in surgical diseases and the use of vaccines and sera in their prophylaxis and treatment.

Serologic reactions are for the purpose of detection of antibodies and based upon the broad general principle that they are specific and their presence in the body cells and fluids indicative of stimulation by the corresponding antigens either in the form of living microparasites during infection and disease, or as a result of active immunization with vaccines. These immunologic tests may be conducted *in vitro* with certain of the body fluids as blood-serum or plasma and cerebrospinal fluid, or *in vivo*, by bringing the antigens or their products in contact with the living cells by cutaneous, intracutaneous, or subcutaneous injection, as in the conduct of such anaphylactic tests as the tuberculin, mallein, and luetin reactions.

Collection of Blood for Diagnostic Tests.—The *amount* of blood required for complement-fixation and other serologic tests is about 5 c.c., and as a general rule should be collected *aseptically* in sterile containers. In collecting blood for the Wassermann test the following points should be remembered:

1. That during active antisyphilitic treatment blood should not be collected until all specific treatment has been suspended for about two weeks.

2. That blood collected during or immediately after an alcoholic debauch may yield a falsely negative reaction.

3. That blood should not be collected just after anesthesia or while the patient has a high temperature.

From **adults** blood is usually obtained without difficulty from a vein at the elbow. The needle should be short, neither unnecessarily large nor too small, and have a short bevel; a needle with a gage No. 18 is satisfactory. Steel needles should be boiled just before use; platinum-iridium needles may be flamed and are particularly serviceable.

A tourniquet should be applied (and I can recommend the use of ordinary garter elastic adjusted with a slip knot as shown in Fig. 540) and the patient requested to open and close the hand, which aids in the distention of the superficial veins. A small area of skin over a vein is painted with tincture of iodin and venupuncture performed. A syringe may be used with advantage or the 5 c.c. vacuum bulb devised by Keidel

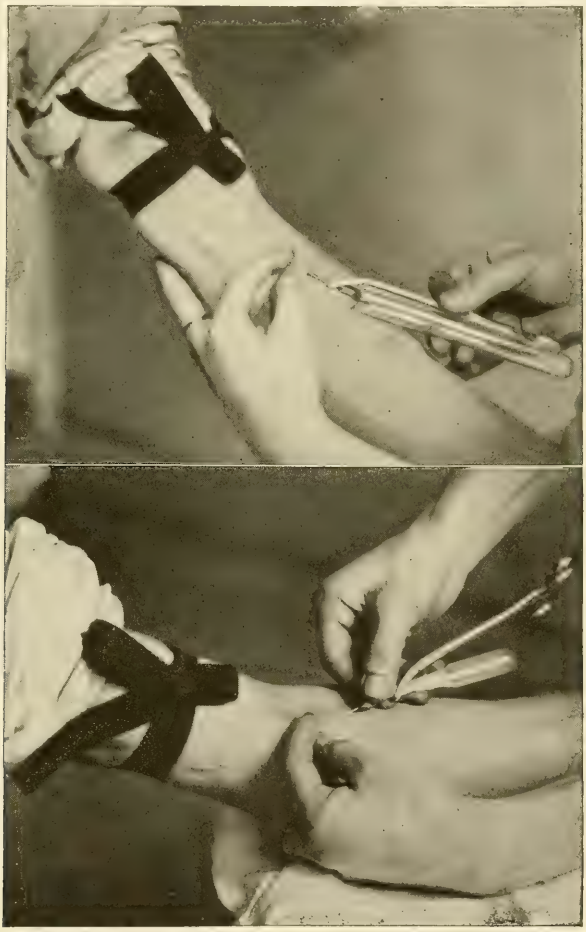

FIG. 540.—METHOD OF OBTAINING BLOOD BY VENIPUNCTURE FOR SEROLOGIC TESTS.

A tourniquet of garter elastic is being employed with a slip knot; above, a plain No. 16 needle grasped with a hemostat has been entered into a vein; below, a Keidel tube is being used, with a hemostat in position to crush the stem of the ampule.

(Fig. 540). To obtain blood with the latter the needle is inserted into a vein, and the capillary end of the ampule crushed with a hemostat through the rubber tubing, blood flowing into the ampule and replacing the vacuum. Whatever method is employed the tourniquet should be released before the needle is withdrawn, the iodin removed with alcohol, and the wound sealed with a touch of flexible collodion.

FIG. 541.—METHOD OF OBTAINING BLOOD FROM AN ANTERIOR JUGULAR VEIN.

The patient is a child six years of age; shows the position of the patient and manner of distending the vein by pressure above the clavicle. A 5 c.c. Record syringe fitted with a No. 20 needle is being used for the withdrawal of blood. The distended vein is painted with tincture of iodin to indicate the position.

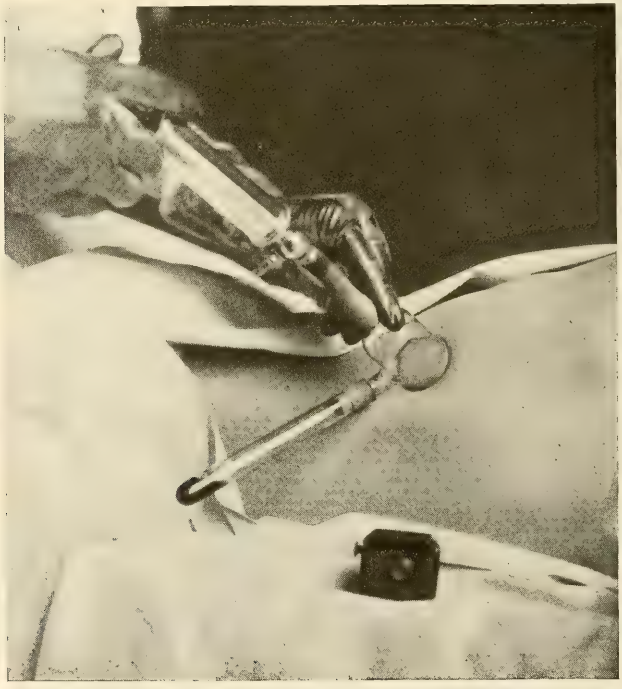

FIG. 542.—METHOD OF OBTAINING BLOOD BY CUPPING.

The child is seven years of age; the Blackfan apparatus is being used and blood collected from a scarified area into a sterile test-tube. (Apparatus is made by Hynson, Wescott & Dunning of Baltimore.)

If for any reason blood cannot be obtained from a vein or if the patient objects, blood is readily obtained by pricking the end of a cleansed finger rather deeply across the lines and massaging blood into

a small test-tube; a broad-bladed blood lancet, as that of Daland, should be used, never an ordinary needle.

From **children** over one year of age blood may be obtained from a vein using a small needle and syringe, as the external jugular vein (Fig. 541); by wet cupping over an area of skin just below the angle of the scapula (Fig. 542), or by pricking a finger or large toe; in *infants* fifteen months or less in age an external jugular vein may be used or the superior longitudinal sinus, if the anterior fontanel is still open (Fig. 543). The latter operation, first conducted by Tobler,[1] and since highly recommended by many pediatrists, is conducted as follows:

The needle and syringe should be carefully sterilized by boiling and the whole operation conducted in an aseptic manner. The skin is carefully cleansed and sterilized with tincture of iodin; the puncture is

FIG. 543.—METHOD OF OBTAINING BLOOD FROM THE SUPERIOR LONGITUDINAL SINUS AND INJECTING WITH A SYRINGE.

The child is six months of age; the shape and size of the anterior fontanel have been outlined; a 5 c.c. Record syringe fitted with No. 18 needle is being employed, the needle having been entered for about 6 millimeters in the median line at the posterior angle and perpendicular to the sinus.

best made in the median line at the posterior angle (Figs. 544, 545). The needle attached to a 5 c.c. syringe (Luer or Record) should be about gage No. 18, with a short sharp bevel, and is passed inward at a right angle for a distance of about 4 mm., and suction made; if blood does not flow the needle should be passed about 2 mm. further, which suffices for the majority of children up to fifteen months of age. With proper care the operation may be done as a safe, quick, and efficient means for obtaining small amounts of blood from infants. Goldbloom has devised a special needle-holder for the purpose of guarding against passing the needle too far and transfixing the sinus; while it is handy and convenient, the physician accustomed to conducting venupuncture will probably find it unnecessary, and prefer to pass a needle attached to a syringe slowly and carefully, making gentle suction with the piston at intervals to determine when the sinus has been entered.

The transfusion of blood, serum, salt solution, and arsphenamin is easily conducted by this technic, the injections being given with a

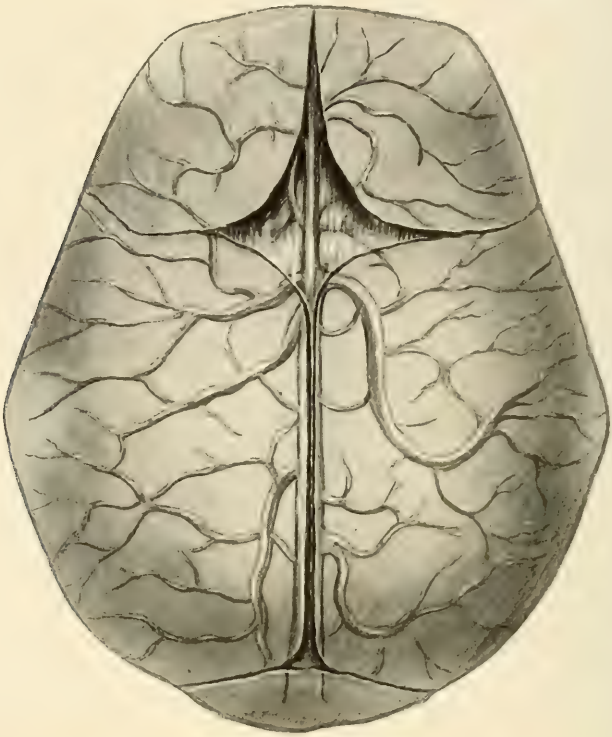

FIG. 544.—THE ANTERIOR FONTANEL AND RELATIONS AND SIZE OF THE SUPERIOR LONGITUDINAL SINUS IN A NEWBORN INFANT.

FIG. 545.—A CROSS-SECTION OF THE HEAD OF A NEWBORN INFANT THROUGH THE POSTERIOR ANGLE OF THE ANTERIOR FONTANEL TO SHOW THE SIZE AND SHAPE OF THE SUPERIOR LONGITUDINAL SINUS.

syringe; in injecting arsphenamin, and neo-arsphenamin, *great care must be exercised*, as disastrous results have followed the injection of these irritating substances into the brain.

Collection of Cerebrospinal Fluid for Diagnostic Purposes and Measurement of Cerebrospinal Fluid Pressure.—The *amount* of fluid required for bacteriologic, immunologic, cytologic, and ordinary chemical examinations is about 5 c.c.; the measurement of pressure may be of value in diagnosis and is made at the time fluid is withdrawn by lumbar puncture.

Certain **precautions** should be observed; lumbar puncture and withdrawal of spinal fluid should never be considered harmless procedures, and should be undertaken only with a full realization of the possible dangers and particularly if the patient has some chronic intracranial lesion. The withdrawal of fluid, and especially its rapid withdrawal with the patient in an upright position, may create sufficient negative pressure in the brain stem to produce hyperemia, hemorrhage, and foraminal hermia, *i. e.*, the engagement of the brain stem in the foramen magnum; hyperemia and reflex disturbances of the choroid plexus may be followed by hypersecretion of fluid, with increased intracranial pressure, which are probably responsible for the headache, vertigo, and vomiting sometimes following the operation, rather than the leakage of fluid into the epidural tissues following withdrawal of the needle. In view of the great number of times lumbar puncture is performed the percentage of accidents and complications, however, are comparatively small, and the operation may be done with considerable safety if certain precautions are observed, as follows: (1) Have the patient lying on the side rather than sitting; (2) evacuate slowly and preferably measure the pressure after the escape of every 1 to 2 c.c. when drawing fluid from persons with choked disk and suspected to be suffering with brain tumor; (3) never remove more than 5 c.c. of fluid for diagnostic purposes unless the pressure is high, due to increased volume of fluid in meningitis; (4) stop if the patient complains of headache; (5) keep the patient in bed for eighteen to twenty-four hours. In common with many others I have frequently permitted patients to be up and about after withdrawal of spinal fluid without any ill effects, but believe that this practice has been responsible for several instances of lumbar puncture headache and consider advisable the precaution of routinely keeping the patient in bed for at least eighteen hours.

The **needle** used for lumbar puncture should be selected with care and be neither too large nor too small. In my experience only two sizes are required, one with an outside diameter of 1 mm. (gage No. 19) for the practically painless puncture of persons and particularly adults in whom there are no symptoms of infectious meningitis and the spinal fluids of normal consistency, and a second of larger caliber (gage No. 15) for use when suppurative meningitis is suspected, in which case the spinal fluid may be denser and flow less easily (Fig. 546). For infants both needles may be cut in half and properly pointed, although these smaller sizes are not absolutely necessary. Needles are available made of platinum and of steel; the former bend very easily when brought in contact with bone, and thus protect the patient, but likewise are easily bent in the operation and deflected from the proper course by muscular

movements, and for these reasons I prefer the latter. It is important for the needle to have a short beveled tip and not a very sharp point (Fig. 547).

The **operation** is conducted as follows: (1) The patient may either sit upright or lie horizontally on the edge of a table or bed on the left side (Fig. 548); as previously stated, the latter position is preferable, being safer, less apt to cause headache, better for pressure readings,

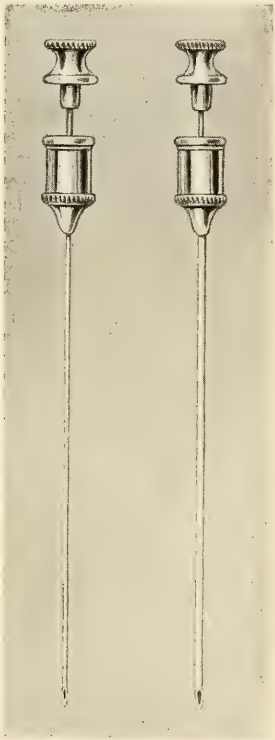

FIG. 546.—BABCOCK NEEDLES FOR SPINAL PUNCTURE.

The needle on the left is gage No. 19 with an inside diameter of 1 millimeter, and recommended for routine spinal puncture and intraspinal injections when the spinal fluid is of normal consistency. The needle on the right is gage No. 15 with an outside diameter of 1.75 millimeters, and recommended for spinal puncture and intraspinal injections in suppurative meningitis with thickened spinal fluid. Both needles fit the various sizes of Record syringes.

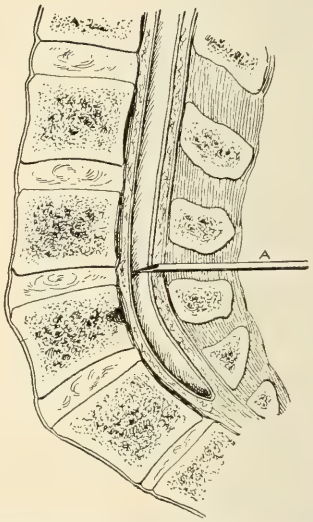

FIG. 547.—AN IMPROPERLY CONSTRUCTED NEEDLE WITH THE OPENING SO LONG AND BEVELED THAT HALF OF THE OPENING MAY BE WITHIN THE DURAL SAC AND HALF WITHOUT, ALLOWING ESCAPE OF FLUID INTO THE EPIDURAL SPACE. (From Frazier's "Surgery of the Spine and Spinal Cord," D. Appleton & Co., New York.)

and essential for children. With the sitting posture, however, lumbar puncture is an easier operation; the patient may either sit straddling a chair or on the edge of a table with the body well bent forward and the arms folded over a pillow in the pit of the abdomen (Fig. 549). The patient should be comfortable, relaxed, and the back well arched to widen the interarcual spaces. (2) The skin of the lower lumbar region should be cleansed with soap, water, and alcohol, and the "soft spot" between the spinous processes of the fourth and fifth or third and fourth

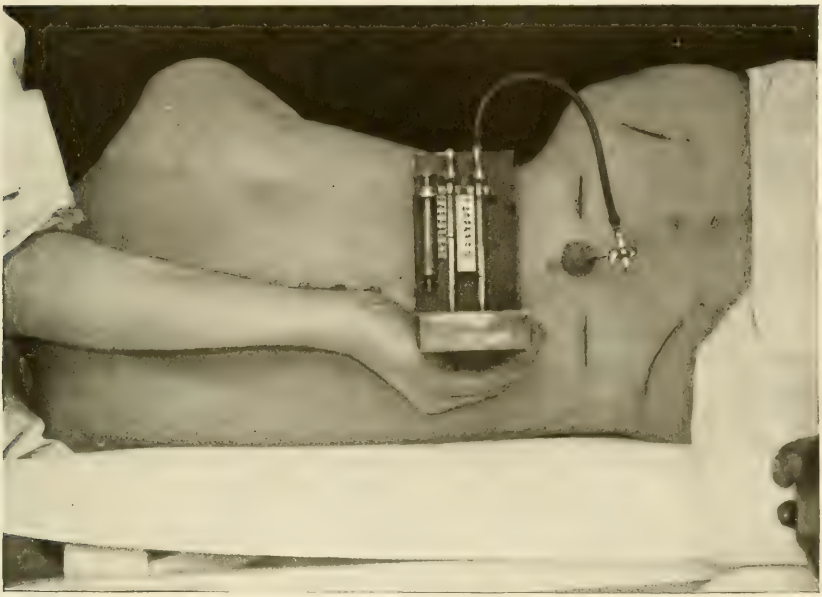

FIG. 548.—SPINAL PUNCTURE IN THE RECUMBENT POSTURE AND MEASUREMENT OF SPINAL FLUID PRESSURE WITH A LANDON MERCURIAL MANOMETER.

The special needle is in position and the manometer adjusted for reading of the pressure before spinal fluid is collected; the reading in this instance was 20 mm. of mercury. The instrument is made by the Harvey E. Pierce Co. of Phila. (From Frazier's "Surgery of the Spine and Spinal Cord," D. Appleton & Co., New York.)

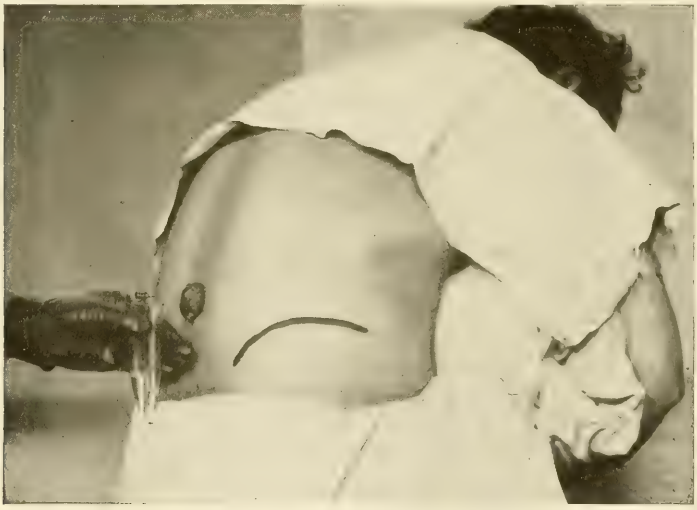

FIG. 549.—SPINAL PUNCTURE IN THE SITTING POSTURE.

The patient is an obese adult male, bent well forward over a folded pillow; the crests of the ilia are outlined. The needle has been passed between the third and fourth lumbar vertebræ in the median line; spinal fluid is being collected in sterile graduated centrifuge tubes.

lumbar vertebræ located and the area painted with tincture of iodin. In fat or muscular persons this spot may be located by a line between

the crests of the ilia. It is essential to locate the spot exactly in the median line, and this is easier in the sitting than in the reclining posture. The operator's hands should be gloved, all instruments sterilized, and the operation conducted aseptically. (3) The skin over the "soft spot" is now infiltrated with a sterile 0.5 per cent. solution of eucain or novocain injected with a fine needle, a whitish elevated patch about the size of a dime being produced (Fig. 550); the needle is now slowly passed vertically and the deeper tissues anesthetized to the depth of the hypodermic needle. (4) The spinal puncture needle is now grasped and passed inward in the median line and slightly upward; a quick, powerful thrust is unnecessary and dangerous. The passage should be made in a gentle,

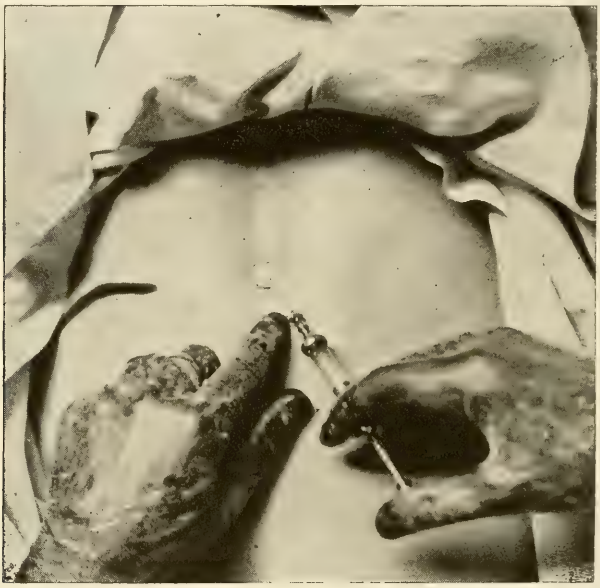

FIG. 550.—METHOD OF PRODUCING LOCAL ANESTHESIA IN SPINAL PUNCTURE.

The patient is an obese adult male; the crest of the right ilium is outlined and the "soft spot" between the third and fourth lumbar vertebræ located. An *intracutaneous* injection of sterile 1 per cent. novocain is being made with a 1 c.c. Record syringe fitted with a No. 26 needle. The position of the needle will then be changed to the perpendicular and the subcutaneous tissues infiltrated as far as the needle will reach.

deliberate manner without force in order to avoid injury to bone or the danger of breaking the needle. The distance to be traversed depends upon age and muscular development; Levinson found the distance 2 to 4 cm. in children up to twelve years of age and from 4.1 to 10 cm. in adults. Upon entrance of the needle into the subarachnoid space there is a peculiar "give way" which is characteristic. (5) The stylet is now withdrawn, and before more than a drop or two of fluid have escaped the manometer is attached as shown in Fig. 548 and the reading made. (6) The fluid is now collected aseptically; I use two sterile graduated centrifuge tubes, collecting the first cubic centimeter in No. 1, about 2 c.c. in No. 2, and the final 2 c.c. in No. 1. The spinal fluid in No. 1 is used for culture and the Wassermann test where the presence

CEREBROSPINAL FLUID EXAMINATION

Name: *Age:* *Ward:* *Date:*
Clinical Diagnosis: *Physician:*

Pressure	Amount	Physical Properties	Cells per c. mm.	Differential Cell Count			Protein Tests			Wassermann Reaction	
				Lymph.	Polys.	Endothel.	Pandy	Noguchi	Kaplan	Blood	Spinal Fluid

Colloidal Gold Reaction

Registry No.	Color Reactions	Dilutions of Spinal Fluid										Remarks
		1 1 : 10	2 1 : 20	3 1 : 40	4 1 : 80	5 1 : 160	6 1 : 320	7 1 : 640	8 1 : 1280	9 1 : 2560	10 1 : 5120	
5	Colorless											
4	Pale blue											
3	Blue											
2	Lilac or purple											
1	Red-blue											
0	Red—unchanged											

Bacteriological Examination

Smears: *Culture:* *Animal Inoculation:*

Additional Chemical Examinations

Quantitative Dextrose: *Quantitative Protein:* *Quantitative Chlorids:*
Qualitative Dextrose: *Examined by:*

FIG. 551.—A CHART USED BY THE AUTHOR FOR RECORDING THE RESULTS OF EXAMINATIONS OF CEREBROSPINAL FLUID.

of a few blood-cells does no harm; the fluid in No. 2 is used for the cell counts, globulin, and colloidal gold tests. (7) The needle is now with-

drawn, the iodin removed with alcohol, and the wound sealed with a wisp of sterile cotton and flexible collodion.

The **normal pressure** of cerebrospinal fluid varies greatly according to technic, and readings are of value only when a uniform method is employed. The normal pressure for adults, in a quiet horizontal position with the mercury manometer of Landon, is from 6 to 10 mm., with an average of 8 mm.; with the water manometer of Levinson, from 130 to 150 mm. The pressure of children is about one-third less, being 45 to 90 mm. of water and 0 to 4 mm. of mercury. Pressure in millimeters of water may be expressed in millimeters of mercury by dividing by 13.

Cerebrospinal fluid pressure may be increased in a variety of conditions: (1) In certain cases of congenital or acquired internal and external hydrocephalus with hypersecretion and normal or impaired absorption; (2) in acute and chronic meningitis; (3) in acute meningeal congestion, the so-called "serous meningitis"; (4) in hemorrhage, and (5) in various space-restricting lesions, such as tumors and fragments of bone and localized chronic inflammatory changes.

The **disposition** of the fluid is important; **cultures and total cell counts should be made immediately** with warm fluid, the latter in the bedroom unless a laboratory is at hand. Chemical and immunologic examinations can be made later; the chart shown in Fig. 551 has been found quite useful for recording the results of examinations.

Two serologic tests are of great value, namely, the complement-fixation test for syphilis and the Lange colloidal gold test for neurosyphilis; aside from these, physical and bacteriologic examinations, total and differential cell counts, protein (globulin), dextrose, and chlorid determinations possess considerable value in the diagnosis of not only the various forms of acute and chronic meningitides but also in such surgical diseases as injuries to the spine, cord, and membranes, tumors of the cord, meninges, and spinal column, etc.

DIAGNOSTIC SEROLOGIC REACTIONS

Complement Fixation in Syphilis (the Wassermann Reaction).—The complement-fixation test for syphilis has proved of great value in all branches of surgery; unfortunately, the test is somewhat complicated and subject to technical errors and particularly in the hands of inexperienced workers, but, as Vedder well says, "one is impressed by the fact that the Wassermann reaction must be a test of most surprising merit to have survived all the clumsy technic that has been perpetrated in its name."

It is customary to express the **diagnostic value of the Wassermann test** with figures showing the percentage of positive reactions observed by different investigators in the different stages of syphilis. While these figures are of value in discussing the diagnostic merit of the test in the primary and secondary stages of the disease when the lesions and symptoms are sufficiently manifest to render clinical opinions trustworthy, in the latent and tertiary stages the clinical manifestations of syphilis may be so diverse and the history given by a patient so mislead-

ing that clinical opinions are apt to vary and prove erroneous when checked by necropsy examinations.

In the **primary stage** of syphilis the diagnosis is frequently best made by means of direct examination of the secretions of the lesion for Treponema pallidum with the dark-field illuminator; in primary lesions about the lips and mouth, however, due precaution must be exercised against mistaking one of the several varieties of spirochetes, and particularly Spirochæta microdentium, to be found in this locality and especially about the gums, for Treponema pallidum. In this stage, however, the Wassermann test is also of value, and particularly if the microscopic examinations cannot be made; the time of appearance of positive reactions with blood-serum varies according to the delicacy of the technic employed, the severity of the infection, and age of the lesion, but the figures given by Craig, who has had a particularly good opportunity for observations in the Army, are acceptable for expressing the diagnostic value of the test in this stage of the disease: "36 per cent. of cases have given a positive reaction by the end of the first week after the appearance of the initial lesion; almost 60 per cent. by the end of the second week; almost 70 per cent. by the end of the fourth week, and over 80 per cent. by the end of the fifth week after the appearance of the chancre."

It is to be emphasized that a single negative reaction does not exclude the disease; tests should be repeated at intervals of three to five days until the diagnosis is established to obtain the earliest possible serologic evidence of the infection if this is necessary, in order that treatment may be begun as soon as possible; *best results in the treatment of syphilis are obtained when instituted before the Wassermann becomes positive, and pushed with sufficient vigor to prevent the blood-serum from ever giving a positive reaction.*

In the **secondary stage** of untreated syphilis the complement-fixation test may be expected to yield from 95 to 100 per cent. positive reactions; a negative reaction is of no value in excluding the disease, but almost invariably repeated tests result in the appearance of strongly positive reactions.

It is probably in **tertiary syphilis** that the complement-fixation test has its greatest value; syphilis is so diverse in character and may be responsible for so many varied clinical conditions that the test has become well-nigh indispensable as a diagnostic aid. There is no limit to the time following infection in which positive reactions may not be found.

In cases of untreated and active tertiary syphilis the reaction is positive in about 96 per cent. of cases; in cases receiving more or less treatment the reactions are positive in from 80 to 85 per cent. In a large percentage of cases of syphilitic iritis, aortitis, aneurysms, gummas, and ulcers of various organs and tissues, etc., the reaction is positive and possesses great diagnostic value.

The test with blood and cerebrospinal fluid has proved especially valuable in the diagnosis of neurosyphilis; in paresis the serum and spinal

fluid yields positive reactions in from 92 to 100 per cent. of cases. In untreated and active tabes dorsalis the blood-serum reacts positively in about 95 per cent. of cases and the cerebrospinal fluid in about 60 per cent.; in treated cases the percentages are lower. It is a peculiar fact that in neurosyphilis the cerebrospinal fluid alone may yield positive reactions and should be examined whenever the blood-serum reacts negatively.

In cases of **latent syphilis** the positive complement-fixation reaction may constitute the only evidence of the existence of the disease, and prompt institution of treatment may prevent the development of active lesions, which are so likely to follow. It has been said that a diagnosis of syphilis should never be based upon the serologic test alone, but in a considerable number of cases there are no other means, and an undoubted positive reaction observed with an acceptable technic may be taken as evidence of the disease. Recent pathologic investigations of Warthin have shown that the complement-fixation test is not too sensitive, but rather not sensitive enough, in view of the fact of the number of times treponemata are to be found in the tissues of syphilitics giving negative reactions during life.

In manifest untreated **congenital syphilis** of children the complement-fixation test is positive in from 97 to 100 per cent. of cases; in children exhibiting the lesions of late congenital syphilis the percentage of positive results is from 80 to 85 per cent., and in still older individuals in whom the disease is supposed to be congenital, from 70 to 80 per cent. In congenital mental deficiency, epilepsy, and Little's disease the complement-fixation test has shown that syphilis plays a larger part in the etiology of these conditions than is generally supposed.

The Wassermann Test as a Guide in Treatment.—Citron originally observed that during the mercurial treatment of syphilis the Wassermann reaction gradually became weaker, and finally disappeared. His observations, which have since been confirmed, showed that *the complement-fixation test may be taken as an index and guide to treatment.* It should be the object of treatment not only to dissipate the external and obvious lesions of the disease, but to produce a condition of the blood and cerebrospinal fluid in which the test is permanently negative. The sum total of the experience of investigators from all parts of the world would indicate that a persistently positive reaction means the presence of living Treponema pallida somewhere in the body, and that, if possible, treatment should be continued until the blood and cerebrospinal fluid react negatively over a period of at least two years.

A single negative reaction during or after treatment does not suffice as serologic evidence of cure; the reactions with blood-serum should remain persistently negative over one and preferably two years, tested at intervals of four to six months, and finally an examination of the cerebrospinal fluid should be advised and yield negative reactions when tested in amounts of at least 0.8 c.c. before cure may be pronounced according to our present knowledge. Unfortunately, cases of latent and tertiary syphilis are encountered in whom no amount of treatment serves

to change the positive complement-fixation reactions with blood and spinal fluid; these "Wassermann fast" persons should remain under observation for the balance of life and report to the physician at intervals for thorough clinical examinations, and particularly of the central nervous system, and receive courses of treatment once or twice a year in an effort to keep the disease at a standstill or at least retard its progress.

It is commonly stated that during active treatment the complement-fixation reaction may be negative and later become positive; in my experience this is of infrequent occurrence and, indeed, the reverse has been the tule, that is, the reaction has been more frequently positive at the close of a period of treatment and negative three weeks later. For this reason I believe the tests should be done two to three weeks after specific treatment has ceased, and if negative, should be repeated at intervals of a month for the first six months and at longer intervals for the balance of one to two years. In relapses the positive complement-fixation test usually constitutes the first and most sensitive sign of the disease and may appear weeks and even months before clinical signs and symptoms.

Provocatory Stimulation.—Gennerich[2] first called attention to the apparent fact that a negative complement-fixation reaction may be followed by a positive result after the administration of arsphenamine (salvarsan), this change occurring either within a few hours or two weeks following the injection. The phenomenon designated "*provocatory stimulation*" has excited considerable discussion with opposing opinions; I am convinced that it may occur and prove of value in the serologic diagnosis of doubtful cases and as a further test for cure.

Stokes and O'Leary[3] found the provocative test positive in 18.4 per cent. of 103 cases and of particular value in the recognition of insufficiently treated cases; they have found the test also indicated in persons presenting obscure bone and joint lesions, histories of miscarriages without manifest causes, mothers of syphilitic children without clinical signs of the disease, persons whose blood-serum yields negative reactions, but giving a history of previous positive reactions, mental deviates and constitutionally inferior individuals with suspicious histories, and persons presenting such special signs as bilateral dacrocystitis, chorioretinitis, and retinitis pigmentosa, etc., and yielding negative reactions.

The test is conducted by administering intravenously 0.4 to 0.6 gm. arsphenamine or 0.9 gm. neo-arsphenamine and testing the blood every day thereafter for a week, and again at the end of the second and third weeks unless a positive reaction has been observed; the labor and the expense, therefore, may be considerable, but the results justify both in the occasional case.

Specificity of the Wassermann Test.—So many extravagant statements have been made for the complement-fixation test in syphilis in both a flattering and derogatory way that the average surgeon possessing but a passing interest in the test may be easily influenced in either

direction; as far as I know no one seriously considers the reaction biologically specific, because the tissue extract used as antigen in the test may be prepared of normal and non-syphilitic tissues. But practically the test is highly specific because positive reactions occur in so few diseases other than syphilis, due to the peculiar nature of the antibody concerned in the reaction. A review of the early literature leaves one with the impression that the Wassermann reaction may be positive in all diseases to which human flesh is heir, but work done in the last few years with improved technic and especially by experienced workers, has shown that the major portion of these reports were erroneous and misleading.

Positive reactions may occur in frambesia or yaws, a tropical disease caused by the Spirochæta pertenue, and responding to treatment with arsphenamin even more promptly than syphilis; also in some cases of tubercular leprosy, malaria during the febrile stages, psoriasis, relapsing fever, and possibly immediately after ether and chloroform anesthesia, but not in the host of other diseases mentioned in literature, including scarlet fever and tuberculosis.

It is well for the surgeon to bear in mind that the reaction may be erroneously negative when the blood is tested during or immediately after an alcoholic debauch, and that a syphilitic whose blood yields positive reactions may present lesions, as ulcers and new growths, which are non-syphilitic, as tuberculous or malignant, which, therefore, fail to heal or disappear with antisyphilitic treatment.

Complement Fixation in Gonococcus Infections.—The gonococcus complement-fixation test is of much less practical value than the syphilis reaction. The gonococcus antibody, unless the infection is complicated by underspread metastases, is produced in small amount in the majority of cases and the reactions are frequently erroneously negative, rendering a negative reaction of little import in excluding the possibility of a gonococcus infection. However, when the test is properly conducted the positive reactions are biologically and practically specific, and for these reasons the test may be said to have a greater positive than negative value.

I have found the test of particular value to surgeons in the diagnosis of gonorrheal arthritis, because it is positive in over 80 per cent. of cases. The reaction is seldom positive during the acute stages of gonorrheal urethritis in either sex. In ordinary chronic urethritis, with acute exacerbations and with involvement of the prostate gland and epididymis, the reactions are positive in from 50 to 80 per cent. of cases. In women the reaction is seldom positive until the infection has reached the cervical canal, but is positive in about 60 per cent. of cases of pyosalpingitis and may prove of value in differential diagnosis and in establishing the gonorrheal nature of pelvic infections.

The test possesses some value in determining the fitness of persons for marriage and as a guide to treatment if the reaction has been previously positive and treatment persisted in until consecutive negative reactions are observed. It is to be remembered in this connection that

the administration of gonococcus vaccine or serum is likely to be followed by positive complement-fixation reactions with the blood-serum and be misinterpreted as an indication of the presence of foci of living gonococci.

Complement Fixation in Echinococcus Disease.—In so far as echinococcus disease of the liver is concerned, a review of the literature and particularly the reports of Ghedini, Weinberg, Jiani, Israel, Henius, and Thomsen and Magnusson indicate a general consensus of opinion that antibodies are present in the sera of the majority of infected persons and animals, and that these may be detected by means of a complement-fixation test conducted with aqueous or salt solution extracts of cyst contents as antigen; there is, however, a diversity of opinion in regard to the specificity of the reaction and its practical value in diagnosis, but the test appears worthy of trial.

Complement Fixation and Agglutination in Glanders.—Complement-fixation and agglutination tests have been found reliable and very useful by veterinarians in the diagnosis of glanders among horses and cattle; both tests have likewise been used with success in the diagnosis of human infections. In conducting the agglutination test with human serum a reaction of 1 to 100 and above is considered positive, the normal serum not reacting above 1 to 50. In conducting the complement-fixation test a polyvalent antigen is required; in acute cases running their course in a few days both tests are likely to yield negative reactions.

Complement Fixation and Agglutination in Sporotrichosis and Blastomycosis.—Cases of transmission of sporotrichosis of horses to persons have been recorded, the slowly growing granulomata ending in degeneration being often mistaken for tuberculosis or syphilis; the disease is particularly prevalent among horses in the western states. Several strains of pathogenic sporotricha have been described, but are grouped by Meyer and Aird[4] as one species, designated Sporothrix schenckii-beurmanni. Agglutination and complement-fixation tests have been advocated by Widal and Abrami and others as diagnostic aids, agglutination occurring in dilutions of from 1 to 300 to 1 to 800 in an hour; Moore and Davis[5] have recently reported favorably upon the specificity and diagnostic value of these tests, and point out that while antibodies are readily produced in sporotrichosis, they are not generated at all or with difficulty in blastomycosis, which is a closely related disease.

Complement Fixation in Tuberculosis.—Probably the earliest attempts toward rendering the phenomenon of complement fixation a diagnostic procedure was applied to tuberculosis by Widal and LeSourd in 1901, followed by similar attempts by Bordet and Gengou in 1903, and by Wassermann and Bruck in 1906. The results of these early investigations indicate that the sera of tuberculous persons and animals sometimes contained a complement-fixing antibody, but these occurred too irregularly, and the reactions proved too weak and inconclusive to warrant the use of the complement-fixation test as a practical diagnostic

measure in tuberculosis. Since 1912 the subject has been revived, and many overenthusiastic reports are to be found in literature; undoubtedly, complement fixation occurs with the sera of a certain proportion of tuberculous individuals, but, as is true of complement-fixation reactions in all bacterial infections, the degree of complement fixation is generally weak and frequently doubtful, and a uniformly satisfactory antigen for the test has not yet been evolved.

The major portion of complement-fixation studies in tuberculosis has been devoted to pulmonary forms of the disease and but little attention has been given so far to the reaction in relation to what may be designated as "surgical tuberculosis," that is, tuberculosis of the kidneys, glands, bones, joints, etc. The subject is still in the experimental stage in so far at least as surgical tuberculosis is concerned, but worthy of investigation. A persistently and definitely positive reaction may be taken as an indication of active tuberculosis and prove of some value in differential diagnosis, but is of value only when considered in conjunction with a careful history and thorough physical examination; for example, a person suspected of having tuberculosis of the kidney and whose serum yields a positive tuberculosis complement-fixation reaction, may have active lesions in the lungs responsible for the serum reactions. At the same time the complement-fixation test for syphilis should be conducted with all sera yielding positive tuberculosis reactions; in my experience many of the antigens advocated for the tuberculosis test contain enough lipoidal substances to yield positive reactions with syphilitic sera. A negative tuberculosis reaction has still less value and does not by any means exclude the presence of tuberculosis.

Complement fixation as a diagnostic procedure in surgical tuberculosis may be said, therefore, to have but little diagnostic value with the technic employed at present, but enough reliable work has been done to show that complement-fixing antibodies may be present in the sera of tuberculous persons, and that the subject is worthy of continued study and especially in reference to improving the technic of the test.

Complement Fixation and Agglutination in the Surgical Complications of Typhoid Fever.—In the diagnosis of typhoid spine (spondylitis and perispondylitis), periostitis, arthritis, and cholecystitis as sequelæ of typhoid fever, agglutination and, to a lesser extent, complement-fixation tests may prove of distinct aid. The interpretation placed upon the results of these tests, however, must be conservative, and at least two factors are to be taken into consideration, namely, whether typhoid vaccine has been administered within a period of two years or a mild catarrhal and symptomless cholecystitis associated with a carrier condition be present, either of which may be responsible for a high agglutination titer or positive complement-fixation test with the serum of a person suspected of having a chronic posttyphoidal periostitis or other surgical complication. If these factors can be excluded, persistently positive agglutination titers of 1 : 40 and higher with the serum may be accepted as evidence of a focal typhoid infection, and especially so if the titer becomes higher during or immediately after an

acute exacerbation. The complement-fixation test is more complicated; a positive reaction is of more diagnostic importance than a negative reaction and the test should always be conducted with a polyvalent antigen.

The Abderhalden Ferment Reaction in Cancer.—Many conflicting reports have been made upon the diagnostic value of this reaction in pregnancy, cancer, and other diseases, rendering an opinion of its practical value difficult of evaluation; when the test is performed by a competent serologist following all the prescribed precautions, satisfactory results may be obtained in some cases, but errors beyond the immediate control of the serologist are prone to be present and greatly limit the practical value of the reaction. As the test is more likely to yield falsely positive than negative results, a negative reaction is of some value in excluding pregnancy, and particularly in those occasional cases presenting tumors in the lower abdomen which may be due to advanced pregnancy or neoplasm. Numerous European and American investigators have reported highly favorable results in the diagnosis of malignant diseases, coagulated cancer and sarcoma tissue being used in the dialysation test in the same manner as placental tissue. As it stands at present I regard the Abderhalden test as possessing considerable scientific interest and worthy of further investigation, but of limited practical diagnostic value.

The Miostagmin and Epiphanin Reactions in Cancer.—Among the very large number of immunity reactions employed in attempts to secure a diagnostic test for cancer the miostagmin reaction of Ascoli[6] and Izar[7] is the only one thus far devised that may claim the serious attention of the surgeon. The reaction is founded on the fact that by mixing an antigen and its corresponding antibody there results a reduction of the surface tension of the liquid containing these, which may be demonstrated by counting the number of drops of the fluid in a given volume with a Traube stalagmometer, the term "miostagmin" meaning "small drop." The test is very delicate, but errors due to faulty technic are particularly apt to occur. Burmeister[8] has found a negative reaction of value in excluding cancer, and of more value in differential diagnosis than a positive reaction, *i. e.*, the test has a higher negative than positive value. Very favorable reports upon the diagnostic value of the test have also been made by Blumenthal and Fränkel[9] and by Roffo.[10]

The **epiphanin reaction,** which is based upon similar principles but technically more intricate, has been found to possess considerable diagnostic value in syphilis, and positive reactions have also been found in malignant diseases, as with antigens of carcinoma and sarcoma. Keidel and Hurwitz[11] obtained 16 positive reactions in a series of 24 sera of persons suffering with definite or suspected malignant disease. Burmeister has not found the reaction of much value in the diagnosis of cancer.

DIAGNOSTIC ANAPHYLACTIC REACTIONS

In certain infectious diseases, as tuberculosis, syphilis, glanders, sporotrichosis, and others, the protein of the infecting microparasites may sensitize body cells, that is, bring about an exaggerated or unusual susceptibility to these foreign proteins, which may be detected by the anaphylactic reaction; likewise after the administration of horse immune sera, as diphtheria and tetanus antitoxins, a state of anaphylaxis to horse-serum proteins may be induced and certain persons inherit or acquire by unknown means hypersensitiveness not only to horse and other animal proteins but also to various plant and vegetable proteins, as certain pollens and even foods. This condition of anaphylaxis or allergy to foreign proteins may be expressed clinically by a wide variety of symptoms and lesions referable to the respiratory, cutaneous, and gastro-intestinal tracts; the interests of the surgeon, however, are usually confined to such anaphylactic phenomena, and especially such diagnostic anaphylactic reactions, as may be encountered in tuberculosis, syphilis, and glanders, or following the administration of tetanus antitoxin and other immune sera.

Anaphylactic reactions are highly specific, and the tests are conducted by bringing the particular protein in contact with the body cells by cutaneous, intracutaneous, or subcutaneous application, the resulting positive reactions being expressed by inflammatory changes at the site of application (the local reaction), and under certain circumstances by similar changes at the focus of infection (the focal reaction), which may be accompanied by slight fever and malaise (the general reaction). The positive reaction is an indication of infection and sensitization to a particular protein, and thereby becomes a practical means of diagnosis; in tuberculosis and probably also in other infectious diseases, as syphilis and glanders, the reaction is a sign of active infection, being inaugurated by a focus of infection, increasing with progressive disease or reinfection, and diminishing with healing, and is not a reaction indicative of immunity.[12]

The Tuberculin Reaction in Surgical Tuberculosis.—A positive tuberculin reaction is to be regarded as a symptom, or as another link in the chain of clinical evidence, but is not in itself indisputable evidence that a certain lesion is tuberculous, for it can never decide with certainty an otherwise doubtful diagnosis. Positive reactions may occur with inactive and relatively benign tuberculous infections, and for this reason about 90 per cent. of adults may react positively, the percentage steadily progressing from about 15 per cent. at the end of the first year of life. *A negative reaction, however, is of value in excluding tuberculous processes at all ages; tuberculin has, therefore, a higher negative than a positive value in diagnosis.* The reaction may be negative in tuberculous individuals with measles; also in the early stages of tuberculosis and in overwhelming acute miliary tuberculosis.

For the **conduct of the tuberculin test** the surgeon has the choice of the subcutaneous, cutaneous, and intracutaneous tests. Probably in the majority of surgical diseases the subcutaneous test is best because

of the evidence of a focal reaction which it may give; the cutaneous test is the easiest and may be used when it is desired to learn simply how a patient reacts to tuberculin. The intracutaneous test has the same value as the cutaneous test, but is somewhat more delicate. The ophthalmic test is not now generally employed.

In conducting the **subcutaneous test** it is necessary to have four-hour observations on the temperature and pulse-rate for at least four days prior to the injection of tuberculin, and the temperature should not rise above 99° F. before beginning the test; a very careful physical examination should be made, and the results recorded just before and just after the test in order to detect a focal reaction. This is very important, for it is our main justification for injecting the tuberculin. Koch's old tuberculin is used; I dilute 0.1 c.c. with 19.9 c.c. of sterile physiologic saline solution containing 0.25 per cent. phenol, and inject 0.1 c.c. of this dilution beneath the skin of the arm. This dose carries $\frac{1}{2}$ milligram of tuberculin; if there is no appreciable reaction at the end of forty-eight hours, 0.2 c.c. (1 milligram) are given, and the third dose, if one is necessary, is of 1 c.c. (5 milligrams) at the same interval. The constitutional reaction consists of a rise of temperature of 1° F. or more above the previous maximum with headache, muscle pains, and malaise; the local reaction consists of redness, pain, and swelling at the site of injection, and the focal reaction consists of inflammatory changes about the focus of infection. The small doses employed are designed to give but mild focal reactions; excessive doses and severe focal reactions are harmful and responsible for the present disrepute into which tuberculin therapy has fallen. For children under fifteen years of age the doses should be about one-fifth those given.

The **cutaneous test** of von Pirquet is conducted by abrading the skin of the arm or forearm at two points and rubbing a drop of Koch's old tuberculin (undiluted) into the lower abrasion, the upper serving as a control for traumatic reaction. The tests are inspected at the end of twenty-four to forty-eight hours, a positive reaction showing as an inflammatory areola at least 5 mm. wider than the control area. The reactions vary in severity and have also been classified as premature, delayed, persisting, cachetic, and scrofulous.

The **intracutaneous test** of Mantoux may be conducted by injecting 0.1 c.c. of the same dilution of tuberculin described in the subcutaneous test (0.1 c.c. Koch's old tuberculin diluted with 19.9 c.c. sterile salt solution) *intracutaneously* (Fig. 552) with a No. 26 needle; a positive reaction consists of an inflammatory area appearing in from six to eight hours, reaching its maximum intensity in twenty-four hours, and usually disappearing in from six to ten days.

In the **diagnosis of bone, joint, and glandular tuberculosis** the subcutaneous tuberculin test is likely to be most valuable on account of the focal reaction of hyperemia, swelling, heat, and pain about the lesions. A focal reaction confirms the diagnosis of tuberculous bone or joint disease, and an absence of this reaction excludes, with the highest probability, the presence of tuberculosis.

In the **diagnosis of genito-urinary and pelvic tuberculosis** a positive tuberculin reaction is of little value unless the subcutaneous method is employed and the surgeon is sure of his ability to detect a focal reaction, a proceeding that may be very difficult or, indeed, impossible. A positive cutaneous reaction indicates the presence of a lesion somewhere in the body, without disclosing the nature of the renal or pelvic lesion; a negative reaction, however, is of more value in excluding tuberculosis.

In the **diagnosis of tuberculosis of the eye, ear, and larynx** the cutaneous or intracutaneous tests should be made first, and if found negative or inconclusive, the subcutaneous test may be conducted,

FIG. 552.—METHOD OF GIVING AN INTRADERMAL INJECTION.

The skin has been cleaned with alcohol and pinched up between the thumb and index-finger of the left hand; the needle (No. 26) has been entered *into* the epidermis and 0.1 c.c. of fluid injected. Note the anemic area, indicating that the injection has been *intradermic*. (From Kolmer's "Infection, Immunity, and Specific Therapy.")

but with *extra caution*, because a focal reaction in a tuberculous larynx is dangerous on account of edema; and in the ear, may lead to extension of the disease to the meninges.

In **tuberculous pleurisies,** dry or with effusion, and unaccompanied by evident pulmonary disease, the cutaneous test is apt to be only mildly positive; in the subcutaneous test a focal reaction of increased pain and physical signs may be elicited.

In **tuberculous peritonitis** the tuberculin test is frequently negative; a positive reaction has more diagnostic value, especially in virulent types of the disease developing insidiously with little or no constitutional disturbances.

The Luetin Reaction in the Diagnosis of Syphilis.—Luetin is the term applied by Noguchi to sterile extracts of Treponema pallida injected *intracutaneously* in the skin of the arm in dose of 0.1 c.c. (Fig. 552) as an anaphylactic skin test for syphilis and designated as the luetin reaction. A positive reaction appears in twenty-four to forty-eight hours as a well-defined papule which may become a pustule in the severer reactions. In exceptional cases the reaction may be delayed or torpid and develop a week or longer after the injection. In non-syphilitic individuals the injection of luetin may be followed by slight traumatic and non-specific reactions which recede in forty-eight hours, leaving no induration. The administration of iodids and bromids at the time these tests are made or while these drugs are still in the body fluids may yield well-marked non-specific positive reactions in normal non-syphilitic persons, which the surgeon may readily interpret as specific luetin reactions.[12]

The reaction has been reported positive in about 30 per cent. of cases of primary syphilis, 47 per cent. of cases in the secondary stage, 80 per cent. in the latent and tertiary stages, and about 70 per cent. of cases of congenital syphilis. In neurosyphilis the reaction is positive in about 60 per cent. of cases and positive in about 90 per cent. of cases of visceral syphilis, especially in aortic insufficiency. In my experience the luetin reaction is of value in the diagnosis of those occasional cases of latent, tertiary, and especially congenital syphilis, and cases receiving treatment that fail to react positively with the Wassermann test. I am quite convinced that in the majority of cases a negative complement-fixation test properly conducted with a sensitive technic is better evidence of the absence of syphilis than a negative luetin test; on the other hand, the true luetin reaction is specific and to be accepted as indicating that a patient is syphilitic, even though the Wassermann reaction is negative.

The Mallein Reaction in Glanders.—Mallein is a glycerin extract containing the toxic principles of Bacillus mallei, the etiologic agent of glanders. It is used extensively as a diagnostic agent in veterinary practice, and may be employed as an aid in the diagnosis of human glanders, the subcutaneous or intracutaneous tests being conducted with mallein diluted and administered as described in the tuberculin tests.

The Sporotrichin and Blastomycin Reactions in Sporotrichosis and Blastomycosis.—These tests, conducted by intracutaneous injection in the same manner as the luetin test, have been reported yielding positive reactions of diagnostic value by Meyer,[13] Moore and Davis,[5] and may prove of practical value to the surgeon in the diagnosis of these infections.

The Seroreaction for Anaphylaxis to Horse-serum.—Occasionally persons are encountered who suffer with asthmatic attacks when in close proximity to horses, and this condition is now known as a state of extreme anaphylaxis to horse protein, the infinitesimal amounts of protein given off in the hair and effluvia being sufficient to excite the

anaphylactic reaction; the administration of horse-serum tetanus antitoxin or any other horse immune serum to such persons would elicit *a severe and probably fatal reaction.* Furthermore, surgeons not infrequently encounter persons previously injected with horse immune serum, as diphtheria antitoxin, who require serum treatment as for tetanus, streptococcus, and anthrax infections; the previous injection usually sensitizes a person to the proteins of the horse-serum, so that subsequent injections of serum are apt to produce anaphylactic reactions expressed in the form of serum sickness, or, in a severer manner, if serum is injected intravenously.

FIG. 553.—AN ANAPHYLACTIC SKIN REACTION TO HORSE-SERUM.

The patient was a horse-asthmatic; sterile horse-serum preserved with 0.5 per cent. phenol was applied to the lower abrasion and sterile salt solution with 0.5 per cent. phenol to the upper as a control. The photograph was taken twenty minutes later and shows a positive reaction with a wheal and slight erythema.

This condition of hypersensitiveness to serum proteins may be detected by skin tests conducted as follows: If a patient is known or suspected to be a horse protein asthmatic the reaction may be elicited by rubbing a drop of horse-serum into an abrasion of the skin of the arm in exactly the same manner as in the conduct of the von Pirquet tuberculin test; a positive reaction appears within half an hour as an irregular whitish wheal surrounded by a zone of hyperemia and accompanied by burning and itching (Fig. 553). If this test is negative the *intracutaneous* test should be conducted, and probably is best for routine tests with persons who do not suffer with horse asthma, but in whom hypersensitiveness of a lesser degree is suspected. By means of a fine needle (No. 26) 0.1 c.c. of a 1 : 50 dilution of sterile horse-serum is injected *into* the epidermis of the skin of the arm (Fig. 552); at the same time 0.1 c.c. of sterile salt solution is injected in the skin of the same or opposite arm as a control. A positive reaction appears within five minutes to an hour as a wheal surrounded by a zone of erythema and accompanied by slight itching; in extreme hypersensitiveness flushing of the face, respiratory discomfort, and rapid pulse-rate may be produced. The lesion usually fades rapidly and disappears after a few hours. Methods for desensitizing persons found hypersensitive to horse-serum by these methods, before the administration of serum, are described later.

The Schick Test for Immunity to Diphtheria.—This test may be

of service to surgeons for the detection of a state of immunity to diphtheria, and may be described here, although it is not an anaphylactic reaction, as are the tuberculin, luetin, and other reactions described above. The test is conducted by injecting into the skin a very minute amount of diphtheria toxin equivalent to one-fiftieth the smallest amount fatal for an 8-ounce guinea-pig in four days. This dose of toxin is diluted with sufficient sterile salt solution to make 0.1 or 0.2 c.c. and injected *intracutaneously* (Fig. 552); a positive reaction shows as an area of erythema and edema about the size of a half-dollar at the end of twenty-four to forty-eight hours. It is well to inject at the same time a similar amount of heated toxin into the opposite arm as a control. A positive Schick reaction indicates the absence of natural diphtheria antitoxin in the blood and susceptibility to diphtheria; a negative result indicates the presence of $\frac{1}{30}$ unit or more of antitoxin per cubic centimeter of blood and immunity to diphtheria. Persons reacting negatively do not contract diphtheria and do not require immunization with antitoxin if exposed to the disease; the test has proved very reliable when properly conducted with good toxin, and every surgeon, physician, and nurse apt to be exposed to this disease should know the state of their immunity by means of this simple test.

VACCINES IN THE PROPHYLAXIS AND TREATMENT OF SURGICAL DISEASES

Principles.—It is necessary for the surgeon to possess a good working knowledge of the underlying *principles of active immunization* with vaccines for best results with this form of therapy; their indifferent manufacture and indiscriminate use have brought disappointment to many, and while they frequently fail, unexpected successes appear making it apparent that we are as yet far from a perfect understanding of the subject. In therapeutic immunization the fundamental principle is to stimulate in the interest of the infected tissues the unexercised immunizing capacities of the uninfected tissues; this is especially true in chronic infections, when the use of a bacterial vaccine may be likened to the application of the whip to a lazy horse that is capable of further effort and work. In acute infections, however, while the cells are at work they may be capable of greater effort, but vaccines should be given cautiously, as they may, to use the same simile, act as a whip to a willing and well-worked horse that is unable to respond or does respond, with resulting disastrous overexertion.

It may be stated in general that *autogenous vaccines should be used whenever possible*, especially in the treatment of disease; variants occur among cultures of the same species, as among the pneumococci, streptococci, meningococci, etc., and the injection of one strain may not protect against another, the occurrence of this mistake being reduced to a minimum by using autogenous products. For the same reason it is not advisable to continue the use of the same vaccine over too long a period if no reactions and no improvement are noted; new cultures should

be made to determine if the right micro-organism is being employed, or if re-infection with another has occurred.

It should be remembered, in this connection, that *usual forms of treatment should be given while vaccine therapy is being used;* for example, it is useless to administer a vaccine to a patient with a suppurative fistula or sinus if an infected silk suture is directly responsible for the irritation.

Sensitized vaccines are those composed of bacteria that have been immersed in their specific immune serum taken from an immunized animal or the patient himself; they were first used by Metchnikoff and Besredka with living bacteria, but have since been prepared with heat-killed vaccines. It is believed that such vaccines produce somewhat milder reactions and may be used when plain vaccines produce severe anaphylactic reactions and have failed to produce a satisfactory therapeutic response. Whatever form of vaccine is employed, it is essential that it be properly prepared and not overheated. More recently *lipovaccines* have been used by Warden,[14] Le Moignic and Pinoy, and by Whitmore, Fennel and Petersen for prophylactic purposes. These vaccines are prepared by drying and grinding the bacteria and suspending large doses of sterile material in a sterile oil. The vaccines are given by subcutaneous injection, and on account of slow absorption one large dose may be given, constituting the chief advantage claimed for these vaccines. The reactions, however, are frequently severe, and while these vaccines have been largely employed, and especially in the army, for prophylaxis against typhoid fever, pneumonia, and meningococcus meningitis, it is now believed that the immunizing response is frequently poor and the difficulties of preparation considerable, so that lipovaccines are being discarded in favor of the usual saline vaccines.

Specific and Non-specific Effects of Bacterial Vaccines; Protein Therapy.—The administration of either an autogenous or stock bacterial vaccine may produce beneficial results not only through the production of specific antibodies but also by means of certain general and non-specific agencies grouped by Jobling and Petersen as follows: (1) The selective stimulation of the hematopoietic tissues by a non-specific stimulus, resulting in the production of specific antibodies; (2) the production of hyperleukocytosis; (3) the production of fever; (4) the mobilization of proteolytic and lipolytic ferments, and (5) an increase of antiferment. In many cases vaccines have a profound and favorable influence upon metabolism, increasing elimination and attended by an increase of body weight. There are now numerous reports in literature, and particularly by Kraus,[15] Luedka,[16] Miller and Lusk,[17] and Nolf,[18] bearing upon the favorable results attending the treatment of certain of the acute infectious diseases, notably typhoid fever and various forms of arthritis, with intravenous injections of stock typhoid and colon bacillus vaccines, or even with solutions of proteins and proteoses, chiefly peptone. While these effects may be gained by subcutaneous and intramuscular injections of large doses, best results have followed the intravenous injection of very small doses;

undoubtedly these non-specific effects following the intravenous injection of a variety of proteins, bacterial and otherwise, and designated "protein therapy," are destined to attract greater attention and are worthy of the serious consideration of the surgeon in relation to vaccinotherapy in order that both the specific and non-specific effects may be secured.

Administration of Vaccines.—Bacterial vaccines are generally administered by aseptic subcutaneous and intravenous injection; the most suitable localities for subcutaneous injections are where the tissues are loose and muscular activity quiet, a new site being chosen for each successive injection. Intravenous injections are given in a vein at the elbow with a small syringe and fine needle. As the administration is frequently followed by a temporary depression of resistance and a feeling of lassitude, the injections are, as a rule, best given during the afternoon and evening, the night's rest aiding in overcoming the depression. It is well not to immunize during the menstrual period, as reactions are apt to be more marked. When intravenous injections are given the reactions are apt to be severe and it is advisable for the patient to remain in bed for at least twenty-four hours following the injection.

No fixed rules regarding *dosage* can be given, as this varies according to whether the infection is acute or chronic, the nature of the microorganism, and the general condition and age of the patient. The opsonic index has been largely abandoned as a guide, the reaction and condition of the patient now governing the dosage. In acute infections the dose should be small and frequently repeated; in chronic infections larger doses may be given at longer intervals. Children tolerate relatively large doses of bacterial vaccines, but the dosage should depend on the weight and not on the age of the child.

For adults I prepare the following doses of various vaccines for *subcutaneous injection* in the treatment of subacute and chronic surgical infections; for the first dose one-half these amounts or 0.5 c.c. are given, and the injections repeated at intervals of five to seven days with the same or gradually increasing doses as necessary to secure mild reactions:

Staphylococci (all varieties)	1,000,000,000	per cubic	centimeter
Streptococci (all varieties)	300,000,000	"	"
Colon bacillus (all varieties)	1,000,000,000	"	"
Typhoid and paratyphoid bacilli	1,000,000,000	"	"
Gonococci	300,000,000	"	"

For *intravenous injections* the doses should be from *thirty to one hundred times less, i. e.*, $\frac{1}{30}$ to $\frac{1}{100}$ of these amounts, and the injections must be given very slowly over a period of several minutes at least; the pulse should be counted during the injection and the administration interrupted or slowed down in case the rate becomes too rapid, which indicates a rapid fall in blood-pressure. Ordinarily the injections are given every other day.

Reactions.—The *local* effects following the subcutaneous administration of vaccines are generally slight soreness at the site of injection;

occasionally, however, severe reactions of an anaphylactic nature are produced characterized by rapid development and considerable edema, erythema, and pain. The *focal* effects about the lesion are exceedinlgy important and serve as a guide to the adjustment of dosage and intervals of administration. I prefer to find slight focal reactions; in furunculosis, for example, when the old lesions discharge a little more, or one or two others threaten to develop during a day or two following the injection, I feel assured that the ultimate result will be good. In tuberculin therapy, however, the trend of opinion is very much in favor of doses so small that no appreciable or constitutional reactions will follow. The *constitutional* effects are usually mild and in the nature of slight fever, malaise, and muscular soreness, but vary within wide limits, depending upon the condition of the patient, the dose, and nervous apprehension.

During the intravenous injection of vaccine or some other protein the pulse-rate is apt to become more rapid, accompanied by deep breathing or dyspnea, slight headache, and often nausea and vomiting. These effects are frequently followed within an hour or two by more or less prolonged rigor, fever, and leukopenia, followed by a drop in temperature, polymorphonuclear and myelocytic leukocytosis, profuse sweating and decrease of pain, and general improvement of the infection; the temperature may continue low during the following twenty-four hours.

Prophylaxis of Rabies (Hydrophobia).—The great value of prophylactic immunization against rabies has received further proof in France during the recent war, the number of bites and rabic infections becoming alarmingly increased; during 1916 the Pasteur Institute of Paris administered treatment to 1391 persons, of whom 6, or 0.43 per cent., died of rabies; 2 of these 6 patients were seized with the disease during treatment, and 1 died less than two weeks after the end of treatment; the deaths of these 3 patients should, therefore, be deducted and the mortality placed as 0.21. During the same period 1008 bitten persons from the district of Lyons received treatment; a single death places the mortality at 0.099 per cent. Since 1900 more than 9000 persons have received antirabic immunization in this city, with a total of 9 deaths, or 0.09 per cent. In Lisbon the mortality from rabies has dropped from 1.75 per cent. in 1895 to zero in the recent five years; it was 0.06 and 0.10 during 1913 and 1914, when 3477 persons bitten by persons, cats, cattle, asses, monkeys, wolves, and dogs received treatment. Of 19,609 persons treated in the Antirabies Institute at Buenos Aires during the past thirty years, only 62 died later than fifteen days after completing treatment, a mortality of 0.031 per cent. Of 425 persons treated in California during 1913 and 1914, bitten by dogs, cats, coyotes, cows, and horses, positive findings of rabies being found in the state laboratory in over 98 per cent. of these animals, the mortality was 0.491 per cent.

Manufacturing biologic laboratories and various state laboratories are now furnishing surgeons with fresh virus ready for administration and full directions, rendering it possible for prophylactic treatments to

be given in the homes of patients; many improvements have been made upon the original Pasteur method for preparing the virus, notably the method of Harris,[19] which utilizes both the brains and cords of infected rabbits dried and preserved in vacuum at —18° C.; the time required for complete immunization with this stronger virus is less than half the time required by the Pasteur method. Of 1159 cases treated with this virus, there were 2 failures, in both of whom the disease developed before the possibility of antibody formation.

Septic Wounds and Sinuses; Vaccine Treatment in Relation to War Surgery.—A great many cases of septic wounds have been treated with vaccines during the recent war, and especially by the English surgeons; it is exceedingly difficult, however, to evaluate the results because of widely divergent opinions. Certainly the results have not been impressive—temperatures did not fall by crisis nor discharges cease as if by magic, and a decision whether vaccines have done any good relies mainly upon clinical impressions. Sir Berkeley Moynihan[20] believes "that a case has been made out for the trial of vaccines in appropriate cases and in suitable conditions," and is thoroughly convinced of the great value of streptococcus vaccine in serious wounds.

A variety of aërobic and anaërobic bacteria have been found in the septic wounds of the war, including the chronic sinuses, with and without sequestra. Among the aërobes, Streptococcus pyogenes has been most frequent and most important; staphylococci, B. coli, B. proteus, B. pyocyaneus, and numerous strains of coliform bacilli have also been found and usually in mixed culture. Of the anaërobic spore-bearing bacilli, B. tetani, B. perfringens (B. aërogenes capsulatus, B. welchii), B. malignant edema (vibrion septique), and B. rodella (B. hubler), the latter closely resembling B. tetani, have been most frequently found, B. tetani, however, in but a small percentage of cases. One of the most remarkable lessons of the bacteriology of war wounds was the long periods of time in which bacteria and particularly the anaërobes remained in the tissues, and especially in sinus cases with sequestra; tetanus and gas gangrene developed many weeks after trivial wounds and operations, and healed wounds frequently broke down with severe sepsis as the result of too early exercise.

It is the general consensus of opinion that vaccines had none or but slight direct influence upon the bacterial flora of septic wounds and sinuses; the basis for vaccine treatment rests upon the principle of producing antibodies and thereby raising the antibacterial power of the serum, providing for its access to the wound as with the use of Wright's solution, and providing proper drainage and dressings. Vaccines are prepared of the aërobic bacteria only, and especially of streptococci; mixed vaccines are advisable if staphylococci, B. proteus, B. coli, and B. pyocyaneus are also present. Such vaccines are given as soon as possible in the attempts to increase the resistance to general constitutional disturbances subsequent to surgical manipulation of the infected tissues, and to prevent the spread of bacterial infection of the tissues in the neighborhood of the wound; Goadby[21] has advised at least four

injections over a period of two weeks preceding operation, and in a large series of cases found that this practice eliminated "flares" and greatly reduced the percentage of secondary hemorrhages due to septic infection. Tidy[22] and Shera[23] have had similar experiences; the presence of anaërobic bacteria was ignored, provided the soldier received these immunizing inoculations and adequate drainage was provided.

Prophylactic immunization among soldiers with antisepsis vaccine prior to exposure to injury has not been tried on a large scale, although strongly endorsed by Sir Berkeley Moynihan, Sir Almroth Wright, and Sir Watson Cheyne; stock vaccines prepared of strains of bacteria from war wounds have been commonly employed in individual cases while autogenous vaccines were being prepared.

The doses should not be too large; the administration of a streptococcus vaccine may begin with 50,000,000 and gradually increased; mixed vaccines may begin with 25,000,000 of each of the important aërobic bacteria present, followed by increasing doses every three to five days over a period of two to three weeks. Operations should not be attempted for at least two days after the last dose.

Staphylococcus Infections; Furunculosis; Abscesses; Carbuncles; Lymphadenitis.—Furuncles, abscesses, and carbuncles are usually caused by some member of the group of staphylococci; carbuncles are occasionally produced by Streptococcus pyogenes either alone or in conjunction with Staphylococcus aureus. Frequently the most rational and successful form of therapy for these infections, including suppurative lymphadenitis, is by means of bacterial vaccines, and the surgeon should always use them as part of the treatment of persons suffering with recurrent infections. Stock vaccines of Staphylococcus aureus or Streptococcus pyogenes may prove satisfactory and may be used until an autogenous vaccine is prepared. During the war whole groups of soldiers were occasionally infected and incapacitated by recurring crops of furnucles. Prophylactic inoculation with polyvalent staphylococcus vaccine has been suggested in the management of similar conditions in war and in civil practice.

In the treatment of staphylococcus infections the initial dose for an adult should be 500,000,000 cocci injected subcutaneously in order to secure a slight focal reaction, followed at intervals of five to seven days by slightly increasing doses until a maximum of 1,000,000,000 cocci are given. Usually six or more doses are required, and it is my practice to give a second series of two to four injections about six months later to reinforce immunity, even though the patient is free from infection.

Streptococcus Infections; Erysipelas; Septicemia.—Erysipelas is usually caused by a streptococcus which is frequently difficult to secure in pure culture from the ordinary cases of this disease; treatment with stock streptococcus vaccines has usually proved unsuccessful. In recurring erysipelas an effort should be made to secure the micro-organism, inasmuch as an autogenous vaccine in dose of 100,000,000 cocci every five days for six or more doses has in some cases aided in bringing about apparent cure.

I have found autogenous streptococcus vaccine of distinct value in the treatment of **streptococcus adenitis** in scarlet fever and diphtheria in conjunction with the usual surgical measures; a polyvalent stock vaccine of scarlet fever streptococci given early in the disease appeared to prevent and lessen the severity of secondary streptococcus infections in this disease.[24] Wright has found small doses of streptococcus vaccine particularly efficacious in erysipelas and lymphangitis following war wounds.

In **septicemia** vaccines have been found by Deaver, DaCosta, and Pfeiffer,[25] and other surgeons of limited value in the treatment of streptococcus and Staphylococcus (aureus) bacteremias complicating septic wounds and puerperal sepsis, and especially in overwhelming infections; an opinion on their value in streptococcus infections is difficult to state because of the tendency of these infections to become self-limited. I am quite sure that when these vaccines are employed they should be autogenous and administered in small doses early in the disease while the patient's resistance is good; a stock vaccine may be given while the cultures and an autogenous vaccine are being prepared. I prepare such vaccines from streptococci secured in blood-cultures or from intrauterine and wound cultures, containing 100,000,000 cocci per cubic centimeter, and commence treatment with 0.1 c.c. by subcutaneous injection, repeating every three days with slightly increasing doses. In streptococcus bacteremia antistreptococcus serum in large doses should also be given intravenously as early as possible. Champtaloup[26] has recently advised three injections of streptococcus vaccine in doses of 100,000,000, 250,000,000, and 500,000,000 for expectant mothers when the surgeon has reason to fear the development of puerperal sepsis.

Periostitis; Osteomyelitis; Spondylitis.—Autogenous vaccines possess distinct value in the treatment of open suppurative periostitis and osteomyelitis in two directions, namely, for the purpose of immunization over a period of two to three weeks preliminary to operation in order to reinforce local and general resistance, and as an aid in bringing about healing after operation and the removal of sequestra and necrotic tissues. Considerable care should be exercised in order to secure cultures from the *depths* of the lesions and mixed vaccines of the aërobes administered as described for the vaccine treatment of septic wounds.

In the treatment of typhoid periostitis and spondylitis (typhoid spine) successes have attended treatment with stock typhoid vaccine; Allan and Squires[27] also believe that this vaccine may have a prophylactic value in some of the surgical complications of typhoid fever.

Focal Infections; Acute Arthritis; Arthritis Deformans; Gonorrheal Arthritis; Neuritis; Specific and Non-specific Therapy.—In recent years considerable attention has been given the subject of focal infection and its relation to such systemic diseases as acute rheumatic arthritis, arthritis deformans, chorea, neuritis, and endocarditis by Rosenow, Billings,[28] and others; these foci may be located in the head and usually in the form of abscesses at the apices of teeth and pyorrhea alveolaris, in the tonsils or sinuses; also in the genito-urinary

and intestinal tracts of both sexes. The changes in the joints are probably not due to the absorption of toxins from the primary focus alone, but to actual localization of the bacteria themselves. The difficulty in obtaining the causative micro-organism is great, owing to chronicity; but by improved methods Rosenow has succeeded in isolating peculiar streptococci from the excised lymph-glands draining the involved joints, from contracted and diseased adjacent muscles, and from excised portions of the diseased capsule of the joint itself.

In the treatment of chronic arthritis removal of the focus, the judicious use of autogenous vaccines in small doses prepared preferably from the adjacent lymph-glands or tissue itself, together with rest, good air, passive motion, and forced feeding comprise rational procedures yielding encouraging results. The vaccines may be given by subcutaneous or intramuscular injection every five to seven days, beginning with doses of about 100,000,000 streptococci and increasing with the endeavor of obtaining slight focal and general reactions; inasmuch as the streptococci are peculiar, stock rheumatism vaccines are apt to prove of little value; if for any reason the micro-organism cannot be obtained from the joint, those from the suspected primary focus may be used.

Occasionally primary **neuritis** and particularly sciatica are attributed to bacterial irritation from focal infection, and particularly from foci about the teeth and tonsils; Greeley[29] and Zapffe[30] have observed good results following treatment of the foci of probable infection and the administration of autogenous vaccines prepared from micro-organisms from these foci.

In **gonorrheal arthritis** the great difficulty of securing the gonococcus from the diseased joints compels the use of stock vaccines, and I believe they should be used routinely in all cases, as under any condition the infection is likely to be prolonged and tedious, and occasionally really good results are to be attributed to vaccine therapy. In the acute stages the doses should be relatively small, about 50,000,000 cocci being given by subcutaneous or intramuscular injection every three to five days, followed by larger doses as the infection becomes subacute or chronic, until 100,000,000 or more are given in one dose; as a general rule a large number of injections are required, and local treatment of the urethra and prostate and general therapeutic measures are required at the same time.

Within the last few years better results have been reported attending the intravenous injections of vaccines in the treatment of acute and chronic arthritis, including gonorrheal arthritis. Miller and Lusk,[17] Bloch,[31] Cecil,[32] Snyder,[33] Cowrie and Calhoun,[34] and others have used vaccines of typhoid or colon bacilli injected intravenously with particularly good primary results attributed to the non-specific activity of the bacterial protein; Nolf[18] has recently reported equally good results observed during the war in the treatment of arthritis and other acute infectious diseases, following the intravenous injection of peptone. The reactions as previously described are apt to be unpleasant and even severe, but therapeutic improvement does not appear to follow unless mild reactions at least are produced.

The immediate effects are frequently splendid, and particularly after the first dose; most patients experience a relief from joint pains and become quite optimistic. Symptoms generally recur, however, requiring repeated injections, but after a series of treatments many patients appear to have been benefited and a few apparently cured. The surgeon, however, should not be too optimistic, and should bear in mind the pathology of the joints when expressing a prognosis; the peculiar changes, in which there is a proliferation of endothelial cells in the blood-vessels about the involved joints with consequent anemic necrosis, fibrosis, and even bony exostoses, should make it clear that cure in advanced cases will be difficult and, indeed, impossible; if the symptoms are relieved and progression of the disease arrested, much is being accomplished, and more is not to be expected. I believe this form of therapy is to be advised in selected cases only when the salicylates and general treatment have failed; the character of the reaction and the lack of a standardized protein antigen known to be safe in the hands of the inexperienced prevent a wide use of this therapy. If autogenous vaccines can be prepared they should be used in order to secure both the specific and non-specific effects; otherwise a freshly prepared stock vaccine of typhoid bacilli may be employed.

As previously stated under dosage and administration of vaccines, the amounts injected must be small; with both stock typhoid and autogenous streptococcus vaccines the first dose should not be more than 30,000,000 bacteria.

Actinomycosis.—Successes in the treatment of actinomycosis with vaccines are claimed by Whittier,[35] Wynn,[36] Dean,[37] and Malcolm[38]; Frazier[39] was unsuccessful in the treatment of one case of abdominal infection. If potassium iodid fails, the surgeon may try an autogenous vaccine, exercising due precautions in regard to its sterility. I have experienced considerable difficulty in standardizing vaccines of fungi and have found that removal of the growths from solid media with a spatula followed by grinding with weighed amounts of crystals of sodium chlorid and adding sterile water drop by drop until a suspension in isotonic solutions was secured corresponding in density to a bacterial vaccine containing 1,000,000,000 staphylococci was generally satisfactory; after sterilization treatment may begin with 0.1 c.c. injected subcutaneously. In Malcolm's case of two years' duration, iodid being swallowed month after month and pound after pound, two sinuses and a nodule gradually healed under weekly subcutaneous injections of a vaccine containing 4,000,000 to 5,000,000 actino-fragments.

Urethritis; Cystitis; Pyelitis.—There is much diversity of opinion regarding the use of vaccines in the treatment of **gonorrheal urethritis**; in the majority of cases stock vaccines have been employed, and the results have been generally unfavorable. Several English writers, however, have renewed interest in the subject by investigations conducted among soldiers during the recent war; Lumb and others have found that vaccines in large and early doses are of value in the treatment of the usual complications and tend to lessen the frequency of recurrences,

and to shorten the duration of the disease. The doses recommended are considerably higher than hitherto employed; in acute urethritis stock vaccines are given as early as possible, starting with 20,000,000 gonococci and increasing by 20,000,000 twice a week until distinct reactions are observed. In chronic urethritis, prostatitis, and vesiculitis a mixed vaccine containing gonococci, staphylococci, colon bacilli, etc., is given every five days in large and increasing doses.

It is highly probable that different races of gonococci are extant, and that lack of success in vaccine therapy is due in part to the use of stock instead of autogenous vaccines; I can recommend, on the basis of several successes, the practice of making cultures during the acute stages when the gonococci can be secured without the difficulty experienced later, and an autogenous vaccine employed as soon as the acute symptoms begin to subside; in chronic urethritis, in which the gonococci could not be isolated, I have seen good results follow the administration of a mixed vaccine prepared of a polyvalent stock gonococcus vaccine and an autogenous vaccine of micro-organisms recovered from the urethra and prostate gland of individual cases. Bloch[31] has administered the vaccine intravenously, reporting severe local and general reactions followed by rapid subsidence of arthritis, prostatitis, and epididymitis.

Considerable success has attended the use of autogenous vaccines in the treatment of certain types of **cystitis, pyelitis,** and **pyelonephritis** of ascending infection, and particularly those following labor or faulty catheterization in both sexes. Williams and Murray[40] have found small doses of autogenous colon bacilli vaccines of distinct value in the treatment of acute and chronic cystitis of women, although the urine may continue to show the presence of colon bacilli for long periods of time. In subacute cystitis of the male, due to stricture of the urethra or enlarged prostate, or in the female, due to perineal injuries, vaccines are of no aid until the underlying cause is corrected or removed.

During the war Walker and Shera found these vaccines very useful in the treatment of paraplegic soldiers infected by rough-and-ready catheterization at the first opportunity and 90 per cent. of whom later developed cystitis due to Bacillus coli or a staphylococcus, or mixture of these. Shera also calls attention to the possible value of prophylactic vaccination in these cases, a stock polyvalent vaccine being given as soon as possible and before cystitis develops.

It is highly essential that urine be collected aseptically and by catheter in order to secure the causative micro-organism, which is usually a colon bacillus, for the preparation of an autogenous vaccine; as shown by Williams and Murray, the urines of apparently normal women collected under rigid aseptic conditions may show the presence of colon bacilli, and in cystitis several different strains may be found, rendering imperative the use of autogenous vaccines. A vaccine may be prepared containing 500,000,000 bacilli, the initial dose being 0.1 c.c., or 50,000,000, increased every five days.

Tuberculin Therapy in Surgical Diseases.—Theoretically at

least skilful tuberculin therapy should prove a valuable adjuvant in the treatment of subacute and chronic tuberculosis of organs of surgical interest; the danger lies in the administration of too large doses, with the production of severe focal reactions. If small, guarded, and carefully increased doses are administered, so that not more than a degree of fever is produced and none or but mild focal reactions about the lesion or lesions, tuberculin therapy is to be regarded with favor as one part of the general and surgical treatment of the disease. Opinions on its value vary greatly; no one surgeon appears to have had a sufficiently large series of cases of any one form of surgical tuberculosis treated with and without tuberculin to render his experiences conclusive; the majority appear to have expected too much in the way of spectacular results.

In **bone and joint tuberculosis** there is growing opinion that surgery may be obviated or supplemented by tuberculin therapy; in **tuberculous adenitis** considerable good may be accomplished with those glands that have not as yet softened, combined *x*-ray and tuberculin therapy yielding excellent results. In the various forms of **tuberculosis of the eye and ear** tuberculin therapy has yielded exceptionally good results. In **tuberculous laryngitis with ulcer** the course of the disease is usually much more favorable with the tuberculin as part of the treatment with local and general measures; and tuberculin patients with pulmonary tuberculosis appear to develop this complication with comparative rarity. In **tuberculosis of the genito-urinary organs** the prognosis is largely dependent upon the accompanying pulmonary condition and upon the extent of the local process. There is general recognition of the value of tuberculin as an adjuvant to hygienic measures, although great difference of opinion exists as to surgical intervention. If one kidney is involved, most surgeons advise early operation, followed by tuberculin treatment; if both organs are diseased, tuberculin may prove a valuable adjuvant to the treatment.

In **open tuberculosis, tuberculous sinuses,** and other lesions complicated by infection with pyogenic bacteria and particularly staphylococci, it is good surgical practice to prepare and administer an autogenous vaccine over a period of three to four weeks before operation in order to fortify the general and local resistance of the patient, although the bacterial flora of the sinus will not be appreciably influenced; at least four doses of vaccine should be given at intervals of five to seven days and the operation done two or more days after the last dose. After the operation the vaccine may be continued for a month or longer with advantage. Combined tuberculin and bacterin treatment has been found useful in these cases by Willard and Thomas.[41]

In the **administration of tuberculin** the surgeon should so regulate the dose as to secure a slight focal reaction in the form of mild hyperemia about the lesion and not more than a degree of fever; it is well to start with a minute dose and push the dosage rapidly until these signs are observed. A variety of tuberculins are available; in the author's opinion O. T. (Koch's old tuberculin) and B. E. (bacillus emulsion) yield best results, and it is well to interchange during treatment. The

initial dose of O. T. may be 0.00001 c.c., which is 0.1 c.c. of a 1 : 10,000 dilution prepared with sterile saline solution containing 0.3 per cent. phenol as a preservative. Doses are increased by giving 0.2, 0.3 c.c., and so on; when the proper reaction is observed it is well to give the same dose at least five times before increasing. When the patient is taking 1 c.c. of 1 : 10,000 dilution, the next dose may be 0.2 c.c. of a 1 : 1000 dilution, and so on, with 1 : 100 and 1 : 10 dilutions. Injections may be given aseptically with a good 1-c.c. Record syringe and No. 26 needle every four or five days in the subcutaneous tissues; afternoon hours are preferable for the injections. The patient should be taught to take the temperature and preserve a record; the surgeon should inspect the lesion, if this is possible, at frequent intervals about twenty-four hours after injection for the purpose of studying the focal reaction. If pulmonary tuberculosis is present it is necessary to bear in mind the influence of tuberculin on these lesions by changes in the physical signs, and unless the surgeon feels competent to do so, an internist should co-operate in the treatment. If intolerance to tuberculin develops, as shown by depression, loss of weight, and increased local, focal, and general reactions, the intervals of injection should be increased to a week or ten days.

Eye, Ear, Nose, and Accessory Sinuses.—In *diseases of the eye* reference has already been made to the uniformly good results ascribed to tuberculin treatment in tuberculous infections; in various other infections due to staphylococci, streptococci, gonococci, pneumococci, and other bacteria good results have been ascribed to vaccine therapy by Mayou, Vandergrift, Bryan, Maddox, DeSchweinitz, Medalia, and others. In recurrent *styes* autogenous or stock staphylococcus vaccines are of distinct value in connection with other treatment, and particularly correction of errors of refraction; in *acute conjunctivitis* due to injuries followed by infection and in chronic *dacryocystitis* autogenous vaccines are of value as part of the treatment. In *ulcerative keratitis* and *hypopyon* autogenous vaccines are usually readily prepared by good bacteriologic technic embracing proper methods of culturing and the use of blood-agar or other suitable media for cultivating streptococci and pneumococci; they are recommended by several aural surgeons. In *chronic iritis* autogenous vaccines cannot usually be prepared; in intractable cases stock gonococcus and polyvalent streptococcus vaccines may be worth trial. Medalia has advised prophylactic immunization of all cases prior to cataract operations when the conjunctiva contains bacteria that cannot be removed by ordinary methods. In this connection it may be stated that the normal conjunctiva frequently shows the presence of white staphylococci and diphtheroids (B. xerosis), and these do not appear to complicate cataract operations with the usual preoperative preparations; in case there are mild chronic inflammatory changes in the lids or conjunctiva prophylactic immunization may be a precautionary measure of some value.

In chronic suppurative *otitis media* and *mastoiditis* autogenous vaccines are sometimes of aid, although the presence of dead bone and

avascularity of the tissues are unfavorable; Weston and myself[42] have observed beneficial results in some cases of scarlet fever otitis media treated with autogenous vaccines, and Coates[43] believes that vaccine therapy has a distinct place as a therapeutic measure in diseases of the ear, nose, and throat when combined with skilful and intelligent local treatment and surgery.

Vaccine therapy of *chronic infections of the accessory sinuses* has usually been disappointing, probably in large part due to the difficulty of establishing adequate drainage; if vaccines are used they should be autogenous, and the cultures should be made by a rhinologist possessing sufficient skill to secure pus as free as possible of contamination.

SERA IN THE PROPHYLAXIS AND TREATMENT OF SURGICAL DISEASES

Principles.—Some confusion exists regarding the use of the terms "serum" and "vaccine therapy"; **serum therapy** is a process of passive immunization induced for either protective or curative purposes by the injection of the antibody-laden blood-serum of another animal, usually a horse, that has been actively immunized by inoculation with bacteria or their products.

Vaccine or **bacterin therapy,** on the other hand, is a process of active immunization in which our own body cells are stimulated to produce antibodies by the injection of the bacteria or their products. These vaccines, therefore, are not serums, and the indiscriminate use of the two terms is much to be regretted.

While an injection of immune serum owes its principal prophylactic and curative effects to the presence of *specific antibodies* as an antitoxin, bactericidan or opsonin for a particular micro-organism or its products, it is also highly probable that certain *non-specific* factors become operative as discussed under non-specific vaccine therapy, and particularly when these sera are injected intravenously. This is not only true in relation to the administration of an alien serum, as that of the horse, but also to a lesser extent following the injection of a person's own serum or transudate, in autoserum therapy.

Granting that serum therapy could be reduced to the simple proposition of bringing specific antibodies into relation with the micro-organisms, the process remains quite intricate, largely owing to the fact that although different strains of the same micro-organism may possess identical morphologic and biologic characteristics, yet they vary not only in pathogenicity but also in the specificity of the antibodies that they stimulate the body cells to produce. In other words, serum therapy is more specific than it is generally considered to be. It is now well known that the antibodies for one type of pneumococcus and meningococcus may have little or no action upon another type, and the same is probably true of the streptococci, gonococci, and various pathogenic bacilli. In the manufacture of immune sera an effort is made to overcome this difficulty by injecting the horses with a large number of different strains of a micro-organism in order to produce a *polyvalent*

serum, but probably more will be gained in the future by the use of monovalent sera, as our knowledge advances on the recognition of types.

With tetanus bacilli it would appear that the toxins of different strains are quite related, so that immunization of a horse with the toxin of one strain yields an antitoxin capable of neutralizing the toxins of all; the same is true of the diphtheria bacilli, but the toxins of other bacteria, as the gas bacillus, streptococcus, and staphylococcus, are more specific for individual strains. The surgeon, therefore, should *use highly polyvalent sera* unless means for the typing of a micro-organism and the use of a monovalent serum are at hand, which may be the case in pneumococcus and meningococcus infections; if the serum of one manufacturer does not produce a therapeutic response in an individual patient, it is well to use that of another, not only because sera of different laboratories vary in antibody content, but because one may contain the particular antibodies for the particular strain of micro-organism infecting the patient, which the other does not.

In **prophylactic immunization** the antibodies are introduced into our body fluids before infection has actually occurred, or at least in the earliest stage of infection, for the purpose of placing them on guard to destroy the infecting micro-organism or to neutralize its products before it has had an opportunity to produce disease. In other words, we aim to fortify our natural defenses by purchasing antibodies from another animal. In **curative immunization** the antibodies are introduced for the aid they give in overcoming an infection and the relief they afford our hard-pressed protective mechanism. *For these reasons it may be stated that the more acute the infection, the greater is the indication for serum therapy.*

Anaphylaxis in Relation to Serum Therapy.—Occasionally persons are encountered who exhibit asthmatic or hay-fever-like attacks after exposure to horses; these individuals are usually found hypersensitive or anaphylactic to horse protein, and *horse-serum should never be given* to them at all, or only under certain conditions discussed later. The fatalities recorded in literature following the administration of serum have generally occurred among such persons, and while they are so rare in comparison to the enormous number of persons treated annually with some kind of antiserum that many believe unwise, their inclusion in a description of anaphylaxis in connection with serum therapy by reason of the influence exerted upon the profession, many of whom may overcautiously and unwisely withhold the administration of antisera, a better understanding of the subject and the exercise of a few precautions will render serum therapy safer and more efficient and tend to prevent serious reactions.

Persons who have had a previous injection of horse-serum in the nature of diphtheria antitoxin, antimeningitis serum, etc., may develop an anaphylactic reaction after a second injection of serum given weeks or years later in the form of **serum sickness.** While the latter may be severe and is always disagreeable, it is not dangerous and never as serious a matter as the administration of serum to the horse asthmatic,

who generally acquires a state of extreme hypersensitiveness by unknown means. Occasionally individuals who are not suspected as being anaphylactic to horse-serum and who give negative skin tests, may develop at once or within fifteen or twenty minutes after the intravenous injection of serum a more or less severe asthmatic attack with dyspnea and flushing of the face, followed by cyanosis, sweating, cough, general anxiety, and an urticarial eruption. Inasmuch as the intravenous injection of various protein substances in the form of bacterial vaccines or albumoses may produce similar reactions, as discussed on page 712, it is possible that a proportion of these reactions may be of a similar non-specific nature. These immediate reactions rarely occur after intraspinal injections of tetanus antitoxin or other serum.

Typical serum sickness develops about seven to fourteen days after subcutaneous, intravenous, or subdural injections of serum; occasionally the disease appears within a few days and particularly among persons who received serum within a few months before the second injection. A rash, usually of the urticarial variety, but which may be morbilliform or even scarlatiniform, is generally the first sign of the disease, followed by fever, slight enlargement of the superficial lymph-glands, and periarthritis; occasionally there may be considerable edema present with the skin rash for a few hours, or it may occur independently. It is most common about the face and neck and may be so extensive as to close the eyes. After the administration of serum the surgeon should bear in mind the possibility of the development of serum sickness, and particularly the fever, which may otherwise be erroneously attributed to infection or some other cause.

Before the administration of tetanus antitoxin or other antiserum the surgeon should exercise the following *precautions* against anaphylaxis: (1) ascertain if the patient suffers with symptoms suggestive of asthma or hay-fever, and particularly when exposed to horses; (2) whether previous injections of antiserum for diphtheria, meningitis, pneumonia, or tetanus have been received; (3) if possible conduct the cutaneous or, preferably, the intracutaneous skin tests with normal or immune horse-serum as described on page 708. These tests are advisable as routine measures for all persons receiving intravenous injections of antiserum regardless of their histories; they are particularly valuable when the history suggests horse asthma, and in these cases should never be omitted even though but a small amount of serum is to be given subcutaneously.

Desensitization should be carried out routinely with all persons receiving intravenous injections of serum, even though the histories and skin tests are negative. This is accomplished by giving 1 c.c. of the antiserum or sterile normal horse-serum subcutaneously at least one hour before; when the antiserum is to be given subdurally or subcutaneously this preliminary desensitizing dose may be omitted.

Persons giving positive tests, but who are not horse asthmatics, should be desensitized more thoroughly before serum is given intra-

venously or subdurally; the danger and need for desensitization are much less when the serum is administered subcutaneously. Desensitization is carried out by giving serum subcutaneously every half-hour, starting with 0.025 c.c. and doubling the dose at each injection until 0.8 c.c. are given with the sixth dose; if no reaction follows the last dose the serum may be administered very slowly, but interrupted for two to four hours if dyspnea, cyanosis, and rapidity of heart-rate supervenes. The balance of serum may then be given in small doses at intervals of four to eight hours.

Persons who are *horse asthmatics* and yield positive skin tests *should not receive serum intravenously at all; even subcutaneous injections are dangerous.* Desensitization may be attempted as described above, but is not likely to progress far enough to render intravenous injections safe, although if 1 c.c. of serum can be given subcutaneously without reaction, small doses may be given very cautiously subdurally.

For the **treatment** of immediate anaphylaxis, as that form of serum sickness developing fifteen to thirty minutes after the administration of serum, immediate relief usually follows the hypodermic injection of 1 c.c. of 1 : 1000 solution of epinephrin or 0.5 mg. of atropin sulphate ($\frac{1}{100}$ gr.) or both. In the treatment of serum sickness in general the usual calamine lotion with phenol may give relief for the burning and itching skin eruption; at night 1 c.c. of 1 : 1000 solution of epinephrin may be given hypodermically, the urticaria disappearing in a few minutes to a few hours, and permitting the patient to sleep for several hours at least. For the headache and joint pains aspirin or salicylates may be given with sodium bicarbonate.

Administration of Sera.—The Route and Method of Injection and the Amount of Serum Administered are Important Factors in Determining the Success or Failure of Serum Therapy.—In tetanus the serum may be given subcutaneously or intramuscularly for prophylaxis, but intraspinally and intravenously in treatment; in pneumococcus, streptococcus, and gonococcus infections, while the serum may be given subcutaneously or intramuscularly, it is best administered intravenously. Until recent years the doses have usually been ridiculously small; to obtain best results in serum therapy large doses are required, repeated if necessary at short intervals over several days in order to produce maximum effects in the presence of an acute infection.

Serum given *subcutaneously* is slowly absorbed, and a portion of the antibodies may be destroyed or anchored before they reach the blood-stream and focus of infection. Injections should be given where the subcutaneous tissues are loose, where movement is least marked, and, preferably, where pressure upon the parts is least likely to occur, for some soreness, dependent upon the bulk of the injection, is bound to follow. For these reasons injections are best given in the abdominal wall, also in the back, in the region of the lower angle of one of the scapulæ, and the buttocks, but in a bed-fast patient pressure at these points cannot readily be eliminated. When the bulk is small, or less than 5 c.c., the arm may be used.

Intramuscular injections may be given in the muscles of the buttocks, and inasmuch as absorption is much more rapid than occurs after subcutaneous injection, may be the route of choice, if for any reason the serum cannot be given intravenously.

Intravenous injections to adults are usually given by means of a vein at the elbow; in young children this is more difficult and frequently requires exposure of a vein under local anesthesia. In infants the superior longitudinal sinus may be used if the anterior fontanel is open.

Injections may be made with a syringe if the bulk is 25 c.c. or less (Fig. 554); biologic laboratories preparing antisera generally furnish specially constructed syringes for amounts up to 50 c.c., rendering an intravenous injection a comparatively simple matter. Larger amounts of serum are best given diluted with an equal amount of sterile salt solution by some form of gravity apparatus, many kinds of which are on

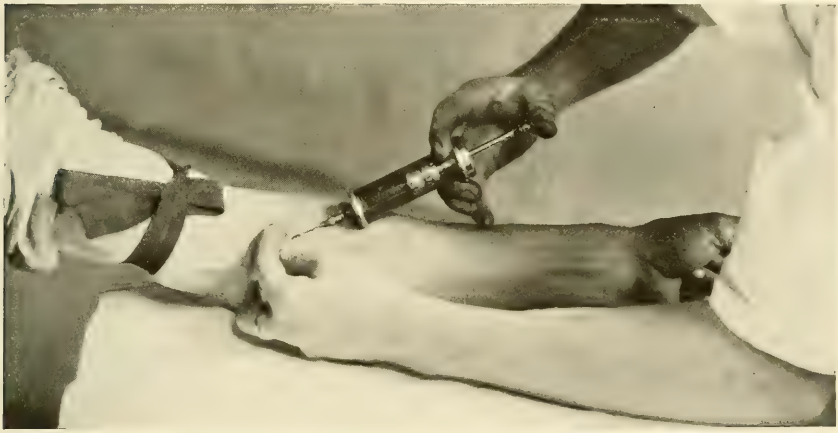

FIG. 554.—METHOD OF INJECTING INTRAVENOUSLY WITH A SYRINGE.

An injection of neo-arsphenamin is about to be given an obese adult male with a 20 c.c. Record syringe fitted with a No. 20 needle; the needle has entered a vein as *indicated by a flow of blood into the syringe;* the tourniquet is about to be released and the injection slowly given. Note method of applying the tourniquet with slip knot, which may be readily released.

the market. Probably the simplest apparatus is best, provided that it can be kept perfectly clean and be readily sterilized by boiling; that shown in Fig. 555 is quite convenient for the surgeon for private practice, more complicated arrangements being utilized if necessary in hospitals.

In giving serum intravenously the surgeon should exercise the precautions against anaphylaxis previously described, and inject slowly. A rigid aseptic technic should be employed and venupuncture may be conducted as described for securing blood for serologic tests. The operation may be made almost painless by infiltrating the skin with a sterile 1 per cent. solution of eucain or novocain, and exposure of a vein is only occasionally necessary in obese individuals.

In giving *subdural* injections of serum, as in the treatment of tetanus, a syringe or gravity method may be employed; the latter is preferable.

Since the syringe of tetanus antitoxin as marketed is not adapted for intraspinal injection, a 25- c.c. Record syringe may be used for the intraspinal injections. The serum should be warmed in hot towels and transferred to a sterile Record syringe; spinal puncture should be made with the patient in the recumbent position, an anesthetic being employed in tetanus for relaxation of the lumbar muscles, employing a gage No. 15 Babcock needle (Fig. 546); the tip of the Record syringe fits this needle perfectly, and after the withdrawal of spinal fluid the syringe may be attached and the serum injected. A gravity apparatus may be made by using the barrel of a Record syringe fitted with about 12 inches of rubber tubing and a metal tip to fit the needle (Fig. 556).

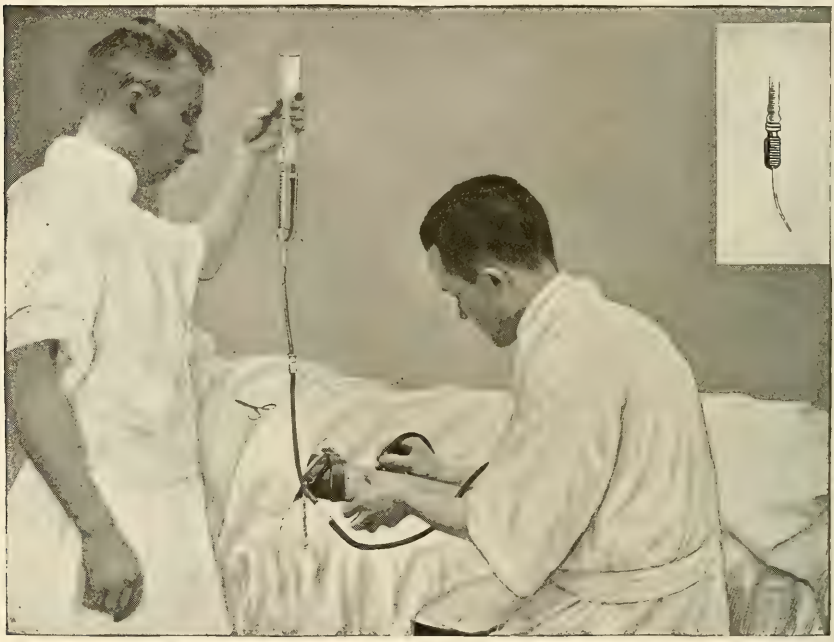

FIG. 555.—METHOD OF INJECTING INTRAVENOUSLY BY GRAVITY.

An injection of 150 c.c. of a solution of arsphenamin is about to be given; shows the elements of the simplest technic. The tourniquet is in position and a firm distended vein is about to be punctured; the needle will then be detached and if *blood flows* will be gently readjusted, the hemostat released, and the injection made. (From Kolmer's "Infection, Immunity, and Specific Therapy.")

Whatever method is employed the serum should be injected slowly and preferably guided by blood-pressure readings; when the pressure falls 20 mm. or more of mercury or other symptoms of collapse appear, intraspinal pressure should be temporarily lowered by withdrawal of the spinal fluid and serum into the syringe, and the injection continued very cautiously until the proper dose of serum has been given.

Serum Prophylaxis and Treatment of Tetanus.—The value of tetanus antitoxin in the prophylaxis and treatment of tetanus in civil practice has been ably summarized by Frazier in Volumes I and VI of Keen's System of Surgery; the experience of army surgeons during the World War has afforded ample confirmation of the great prophy-

lactic and definitely curative activity of the antitoxin, the subject being considered from the standpoints of surgical and serum prophylaxis and treatment by Dr. Fred. T. Murphy in Volume VII, page 96.

Since tetanus bacilli and spores are to be found in dirt and earth, the earth-digging methods of warfare practised during the recent war were responsible for a high incidence of tetanus, and especially in wounds grossly contaminated with dirt and foreign bodies and in wounds involving bones. The sudden demand for antitoxin was met by the preparation of sera below the average in potency, so that disappointments in its protective value were encountered, but with this correction the evidence of army surgeons, as Tizzoni, MacConkey, Bruce, Angerer,

FIG. 556.—INTRASPINAL INJECTION BY GRAVITY.

The apparatus has been prepared with the barrel of a 20-c.c. Record syringe fitted with rubber tubing and a metal tip to fit a Babcock needle. The needle, as shown, is gage No. 19 and reduced about four times the actual size. Tetanus antitoxin is being administered while blood-pressure readings are being made by the auscultory method. (From Kolmer's "Infection, Immunity, and Specific Therapy.")

Gibbon, and others, are overwhelmingly in favor of the high prophylactic value of the serum given subcutaneously or intramuscularly in doses of 500 to 1500 United States units as soon as possible after the injury has been received. Since horse-serum is rapidly eliminated, experience has shown that persons with severe wounds should receive one or more additional injections of 1000 units at intervals of seven days, one injection sometimes failing to protect over a sufficiently long period of time. Aside from the injection of serum, strict and immediate antiseptic treatment of the wound has proved one of the best means of avoiding tetanus.

Army experience has also firmly established the curative activity of

potent serum administered intraspinally and intravenously, although the mortality is only lowered about 20 per cent. and the results not nearly as brilliant as seen in the serum treatment of diphtheria. As shown by Park and Nicoll[44] experimentally and by Nicoll[45] in the treatment of the disease in human beings, the greatest amount of therapeutic activity follows the intraspinal injection of the antitoxin, and this route of administration should be a part of the treatment of the disease, 3000 to 5000 units being injected and repeated every twenty-four hours until the symptoms are markedly ameliorated. At the same time 10,000 to 20,000 units of antitoxin should be given intravenously and repeated if necessary twenty-four hours later; the effects may then be maintained by one or two intramuscular injections of 5000 units. The serum treatment of the disease is therefore expensive, but its prophylaxis is not, and serum prophylaxis is so efficient that tetanus is to be regarded as a preventable disease; during the latter years of the war tetanus was comparatively rare and many army surgeons of wide experience saw but few cases.

Serum Treatment of Streptococcus Infections.—Despite the fact that antistreptococcus sera have been used for over twenty years by numerous investigators, opinions regarding their curative value in streptococcus infections of man have been conflicting and, as a rule, unfavorable. A large amount of bacteriologic research during the last few years, and particularly in the army, has shown that there are a great many different varieties of streptococci, and it does not appear possible to prepare immune sera sufficiently polyvalent for routine use. The brilliant results, however, occasionally observed to be attributed to the curative properties of antistreptococcus serum indicate that this treatment of streptococcus infections possesses some value and is deserving of continued trial; better results will probably follow the use of monovalent sera, if streptococci are ever successfully grouped, as have the pneumococci and meningococci.

Practical experience of the last few years has taught that antistreptococcus serum, if given at all, should be *highly polyvalent, given in large doses, by intravenous injection and as soon as possible.* Any attempts to influence a severe infection by injecting 10 c.c. of serum under the skin is almost sure to result in failure; likewise to wait until the patient has become nearly moribund is an error. The serum should be given in doses of 50 to 100 c.c. by intravenous injection, and if the temperature does not begin to fall during the following twelve hours after an initial rise due to the injection, and the patient's condition improve, a second injection should be given, and should be repeated at twelve-hour intervals for at least two or three days if necessary.

In regard to the practical value of the serum in the treatment of severe streptococcus infections of wounds, in septicemia, cellulitis, erysipelas, and puerperal sepsis, it may be stated that when serum is properly administered it does no harm and may do good, and that its use should form a part of the treatment of severe streptococcal infections.

Kaiser[46] has advised the transfusion of whole blood from a convalescent patient if a suitable donor can be found, and Moncany[47] reports a successful case transfused with normal blood; combined treatment with antistreptococcus and autogenous streptococcus vaccine has also been advocated by Burnham[48] and others for infections tending to pursue a prolonged course.

Serum Treatment of Staphylococcus Infections.—Staphylococcus infections are not usually so severe as to create a demand for antistaphylococcus serum, although, according to the experience of Thomas, such sera may be prepared and prove of value in the treatment of carbuncles or other severe infections.

Hooker[49] has recently reported good results in the treatment of severe staphylococcus infections with delayed recovery and poor resistance by the transfusion of whole immune blood from a donor previously immunized by three or more injections of staphylococcus vaccine.

Serum Treatment of Gonococcus Infections.—Antigonococcus serum may prove of some value when properly administered in the treatment of particularly severe and acute gonococcus infections of the male arising by direct extension from the urethra, such as acute prostatitis and epididymitis, acute orchitis, arthritis, and iritis; whereas in former years the serum has been administered in doses of 2 c.c. injected subcutaneously, numerous surgeons reporting favorable results in the treatment of gonorrheal arthritis, which must have been due to nonspecific effects, Corbus[50] has reported more favorable results in the treatment of 24 cases of gonococcus infection by using larger doses of serum—from 36 to 45 c.c.—injected intramuscularly. The serum should be used only in the treatment of those occasionally severe infections with bacteremia and rapid metastases to neighboring organs; 30 to 50 c.c. may be given intravenously and repeated every twelve hours for one or two days until permanent lowering of the temperature and general improvement of the patient's condition are seen.

Serum Treatment of Anthrax.—Owing to difficulty of preparing potent antianthrax serum by the immunization of horses, the value of these antisera in the treatment of human anthrax is difficult to evaluate; furthermore, many persons recover without serum by proper surgical treatment of the pustule, preferably by excision, whereas in internal anthax or any form associated with anthrax bacteremia, the outcome is usually fatal despite the use of serum. Sclavo's serum has been most widely used, the mortality of the disease in Europe being reduced, according to Sclavo, from 24.16 to 6.09 per cent.; this serum has also been used in the United States, although its high cost has frequently prevented the administration of adequate doses. Equally good and, indeed, superior sera have been prepared in this country by Eichorn in the laboratories of the Bureau of Animal Industry, and antianthrax sera prepared by American manufacturers are on the market. Recently Penna, Cuenca, and Kraus[51] have advocated the use of normal beef-serum heated at 56° C. for thirty minutes on two successive days for purposes of sterilization, and administered in doses of 30 to 50 c.c. subcutaneously

or intramuscularly, except in very severe cases, when the serum is administered intravenously; the injections are repeated in twelve, twenty-four, or thirty-six hours, as the case may require.

In an experimental study with Koehler and Wanner[52] I have found that normal beef-sera contain some antianthrax substances, but are without appreciable protective and curative value in the treatment of experimental anthrax infections of mice and rabbits.

In the treatment of malignant pustule I have seen good results in the Philadelphia Hospital for Contagious Diseases with the following plan: (1) Blood-culture as soon as possible; (2) immediate injection of 20 to 50 c.c. of antianthrax serum by intramuscular or, preferably, intravenous injection; (3) wide excision of the pustule under anesthesia and with as little manipulation as possible; (4) antiseptic treatment of the wound with calomel and powdered ipecac; (5) if the blood-culture is positive, 100 to 200 c.c. of serum intravenously every twelve to twenty-four hours until the latter become sterile. Regan and Regan have recently secured a good result in the treatment of the pustule by injecting 10 c.c. of antianthrax serum into the tissues about the lesion. In *internal* anthrax (woolsorters' disease) all the surgeon can do is to administer 100 to 200 c.c. of serum intravenously every twelve hours for two or three days; arsphenamin may also be administered by intravenous injection in the hope of aiding in preserving life.

Bacteriology and Serum Treatment of Gas Gangrene.—The bacteriology of gas gangrene was the subject of a great deal of investigation during the World War because of 0.5 to 3.5 per cent. of wounded developing this dreadful complication with a mortality of 10 to 50 per cent., depending upon how early treatment was given. Until these studies were made Bacillus aërogenes capsulatus (B. welchii; B. perfringens) was regarded as the sole cause of this infection, but experience has shown that pure infections of war wounds with this bacillus were so rare as to be almost negligible. Other spore-bearing anaërobic bacilli were commonly present in gas gangrene, as B. œdematis maligni (vibrion septique) and B. œdematiens (B. bellonensis), although frequently overgrown by other micro-organisms. Of these three anaërobic bacilli—B. œdematis maligni (vibrion septique) and B. œdematiens (B. bellonensis)—are most pathogenic and dangerous.

Bull and Pritchett[53] have found that B. aërogenes capsulatus (B. welchii, B. perfringens) produces an exotoxin in fluid culture-media, and that horses immunized with sterile filtrates containing the toxin produce an antitoxin affording protection to pigeons and guinea-pigs infected with the bacillus or its soluble toxin. The part played by this bacillus in gas gangrene, however, is of minor importance; some investigators regard it as a saprophyte, and Taylor and others doubt that the hemolytic poison produced by its growth in muscles is a true exotoxin for which an antitoxic serum can be produced. While Bull's antitoxin is undoubtedly protective and curative in experimental infections of laboratory animals, the serum has proved generally disappointing in the prevention and treatment of gas gangrene of war wounds; Gibbon

found that it sometimes arrested infections, had no effect on others, and occasionally produced severe reactions.

Antisera have also been produced in the Pasteur Institute of Paris by Weinberg and Séquin,[54] Leclainche and Valleé,[55] and Sacquépeé[56] by immunizing horses with dead and living cultures of B. aërogenes capsulatus (B. welchii, B. perfringens); this serum is designated as antiperfringens or antimicrobial serum in contradistinction to Bull's antitoxin serum; for B. œdematis maligni (vibrion septique), designated as antivibrion septique or anti-edematous serum, and for B. œdematiens (B. bellonensis), designated as anti-œdematiens or antibellonensis serum. In an experimental study of these sera Nevin[57] found that Bull's antitoxin alone was ineffective in mixed infections and that best results followed the use of a mixture of these various antisera. These results appear to be in accord with clinical opinions, namely, that the antitoxic serum for B. welchii alone is unsatisfactory, and that best results in the serum prophylaxis and treatment of gas gangrene may be expected with a mixture of the antisera for B. welchii, B. œdematis maligni, and B. œdematiens or a polyvalent serum secured by immunizing horses with the three micro-organisms and their products. For example, Duval and Vaucher[58] have reported favorably upon the *prophylactic* value of such sera, the mortality rate being reduced from 16 to 3.5 per cent.; of 77 cases of gas gangrene *treated* with serum, 16, or 20.7 per cent., died. Marquis,[59] in the treatment of 10 cases with serum, lost 2, a mortality of 20 per cent.; Rouvillois, Guillame, Louis, Pedeprade, and Thibiérge[60] treated 25 cases, 3 of whom were moribund, with a mortality of 24 per cent. Mairesse and Regnier[61] had 30 cases, or 10 per cent., of 297 wounded men showing gas bacillus infection, develop gangrene after the prophylactic administration of antiperfringens, antivibrion septique, or anti-œdematiens sera, depending upon the bacteriology; of 30 cases receiving curative injections the mortality was 16 per cent.

Van Beuren[62] states that the prophylactic use of antigas serum in the British and American armies yielded favorable and encouraging results, and both the Third and Fifth Interallied Surgical Congresses for the Study of War Wounds reported that antiperfringens serum seemed to have given favorable results as a prophylactic, and that antivibrion septique and anti-œdematiens sera yielded appreciable results, both from a prophylactic and curative standpoint. All investigators are agreed, however, that serotherapy is but an adjuvant to surgery, and that surgical treatment "is still indicated and in no way modified." In general the lowest mortality from gas gangrene treated by operation alone is about 25 per cent., and by operation plus serotherapy about 19 per cent.

In the treatment of gas gangrene best results appear to have followed: (1) A prophylactic dose of polyvalent antigas gangrene serum and tetanus antitoxin; (2) earliest possible surgical treatment and bacteriologic examination of the wound; (3) the administration of sera, either single or polyvalent, according as there are one or more gas bacilli in the wound.

Intravenous injections of polyvalent serum in combination with

deep muscular injections proximal to but in the vicinity of the wound are to be preferred; the total amount injected for prophylaxis should be from 30 to 100 c.c., half intravenously and half intramuscularly. In the treatment of gas gangrene the same amounts of serum should be given and repeated in twelve hours by giving 100 c.c. intravenously and daily thereafter in the same or smaller doses, as indicated. For curative purposes specific and monovalent sera should be used according to the results of bacteriologic examinations if these can be made; if not, a polyvalent serum may be employed.

Normal Serum and Hemotherapy in Surgical Diseases.—Sterile normal human serum has been widely employed in the treatment of various skin diseases and the toxicoses of pregnancy; autoserum therapy, consisting of the administration of the patient's own serum, has been advocated in the treatment of obstinate and chronic dermatoses, the acute infectious diseases, and with the addition of arsphenamin, for the treatment of neurosyphilis by intraspinal injection. Autotherapy has also been practised in the treatment of tuberculosis of serous membranes, as pleurisy and peritonitis, by injecting 2 to 5 c.c. of the effusion into the subcutaneous tissues. A sharp reaction generally follows these forms of serum therapy and the good effects are to be ascribed to non-specific agencies due to the administration of protein substances and constituting a form of non-specific protein therapy previously described.

Sterile normal human, horse, and rabbit sera have been used with considerable success in the treatment of hemorrhage, as melæna neonatorum, hemophilia, purpura hæmorrhagica, hemorrhagic retinitis, intestinal bleeding in typhoid fever, in surgical operations upon icteric persons, etc.; the doses advised have been from 10 to 20 c.c. for infants and children and from 20 to 50 c.c. for adults, administered by intramuscular or subcutaneous injection.

Blood transfusion has also been resorted to in the treatment of localized pyogenic infections, as in cases of sinus thrombosis following mastoiditis in which the jugular vein has been ligated; in bacteremia due to puerperal sepsis or other infection, temporary improvement may follow transfusion with an increase of the patient's vitality, and, if the primary focus of infection can be eliminated, the results may be excellent at a critical period.

CHEMOTHERAPY IN SURGICAL DISEASES

Arsphenamin in Spirochetic Gingivitis (Trench Mouth), Vincent's Angina, and Amebic Infections.—While arsphenamin (salvarsan) therapy has achieved its greatest success in the treatment of syphilis, its influence on certain non-syphilitic diseases has been so pronounced that it is being used in an ever-increasing number of diseases, and its sphere of usefulness increased. It is now known that a proportion of cases of **chronic gingivitis** and **pyorrhea alveolaris** are caused by a variety of spirochetes, or at least these microparasites exert a prominent rôle in these infections, and have received particular attention during the World War in connection with "trench mouth"; *the local*

application by means of a syringe of 1 per cent. neutralized solutions of arsphenamin has proved most efficacious in treatment, and especially in the experience of Barrett and Smith,[63] who have given the subject particular attention. The solution is prepared by dissolving 0.1 gm. arsphenamin in 10 c.c. of sterile distilled water and neutralizing with 15 per cent. solution of sodium hydroxid; the solution may be preserved for weeks by filling 1 to 5 c.c. ampules and sealing with a flame; 1 or 2 c.c. generally suffice for a single treatment in conjunction with other local measures in the form of cleansing.

Arsphenamin has also been reported as yielding good results in the treatment of **angina** due to the fusiform bacillus and spirillum of Vincent; immediate improvement and rapid healing have followed local applications at frequent intervals of a 1 per cent. neutralized solution in water or 50 per cent. glycerin; the latter is prepared by diluting a 2 per cent. neutralized solution in water with an equal part of neutral glycerin. In extensive infections the drug has been administered intravenously, as in the treatment of syphilis.

It is highly probable that arsphenamin not only destroys the mouth spirochetes but also the Endamœba gingivalis (Gros) to be found in a percentage of peridental suppurations; Dutcher[64] has recently reported its successful use in the treatment of balantidiosis, and Winn, Willits, and Gunn[65] in the treatment of dysentery due to Entamœba histolytica, the combined use of emetin hydrochlorid and arsphenamin or neo-arsphenamin yielding a more rapid, less severe, and apparently more efficacious treatment than the older methods.

Arsphenamin in Septicemia, Anemia, and Other Conditions.—Allison[66] and Haythorn[67] have found arsphenamin of value in treating bacteremias, and especially of streptococci, during the early stages, providing the local focus of infection could be reached and eradicated; several cases of puerperal sepsis were particularly benefited, but the treatment was of little or no value in endocarditis, arsphenamin being unable to influence the bacteria in a localized infection.

The hematinic effects of the arsenic in arsphenamin and neo-arsphenamin are well known, and the drugs may prove of value as a form of arsenic therapy in secondary anemias and pernicious anemia; Kall has reported upon the favorable influence of small doses of arsphenamin (0.05 to 0.075 gm.) injected intravenously in the treatment of secondary anemias and nutritional disturbances. Bramwell and others have used the drug in the treatment of pernicious anemia, and a combined treatment with arsphenamin or neo-arsphenamin and blood transfusion has given excellent temporary results, with frequent long periods of relief. For the anemias, neo-arsphenamin is well suited, inasmuch as the doses may be small and administered with a syringe, about 0.4 gm. dissolved in 10 to 20 c.c. sterile distilled water being injected twice weekly for a period of several weeks.

Stokes[68] has recently reported that arsphenamin exerts a good therapeutic effect in combination with a systemic régime and Roentgen rays in various types of papulonecrotic **tuberculids** and **erythema induratum;**

the general effects, with increase in weight and disappearance of rheumatic pains, were especially marked.

Arsphenamin has proved a specific for **frambesia** or yaws, a tropical disease due to Spirochæta pertenue, and the results in treatment have been even more brilliant than in syphilis; also in **relapsing fever** due to S. Obermayer, and **filariasis,** due to Filaria sanguinis hominis; of much interest in connection with Noguchi's discovery of a spirochete in yellow fever is the reports of De Beaurepaire, bearing upon the curative properties of neo-arsphenamin in this disease. Stott[69] and others have found arsphenamin of value in the treatment of chronic malaria when the parasites have proved resistant to quinin.

Chemotherapy in Pneumococcus Infections.—Zentmayer[70] and others have reported very favorably upon the treatment of pneumococcus infections of the eye, and particularly **corneal ulcers,** with daily applications of a 2 per cent. solution of Morgenroth's ethylhydrocuprein hydrochlorid (optochin), a synthetic derivative of hydroquinin, and the hourly instillation of a few drops of a 1 per cent. solution into the conjunctival sac. During the past year Idzumi and myself[71] have found this drug of value in the treatment of experimental pneumococcus meningitis of rabbits and dogs, and suggest its administration by intraspinal injection in doses of 10 to 30 c.c. of 1 : 1000 solutions in sterile distilled water as early as possible in the treatment of this highly fatal disease among persons.

Chemotherapy in Cancer.—Further investigations of Keysser[72] have shown that while Wassermann's selenium-eosin compound, Neuberg's copper-glycocoll salt, and various selenium-vanadium preparations may influence subcutaneous tumors of mice by liquefaction necrosis followed by healing, visceral tumors showed no such softening, and grew and caused metastases and death just as did the tumors in control animals. Frequent handling and injury of the subcutaneous tumors explained in large part the differences and Wassermann's earlier results; McClurg, Sweek, Lyon, Fleisher, and Loeb[73] have found that intravenous injections of colloidal copper and casein may produce inflammatory changes in malignant tumors followed by some reduction in size; in a recent review of the whole subject Weil[74] has concluded that when the results are viewed and studied in a critical manner it is apparent that none of the various methods of treatment advocated so far can lay claim to marked therapeutic effectiveness.[53]

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CHAPTER LIV

RADIUM IN THE TREATMENT OF MALIGNANT AND OTHER DISEASES

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Part I

LAWS AND PRINCIPLES OF RADIO-ACTIVITY, METHODS OF TREATMENT, METHODS OF ESTIMATING DOSAGE, ETC.

Brief History.—The discovery of radium was not a matter of chance, but the result of a well-thought-out campaign of research. In 1895 Roentgen announced the discovery of a new type of rays, which he called *x*-rays. These rays pass through solid substances (even those opaque to ordinary light), produce fluorescence when they fall upon certain salts, and darken photographic plates, etc. In 1896 Henri Becquerel, following out a suggestion of Henri Poincare's, that rays similar to *x*-rays might accompany the excitation of fluorescence in salts, discovered that, as a matter of fact, the chemical element uranium and substances containing it, whether fluorescent or not, produce spontaneously rays capable of passing through opaque matter and of darkening a photographic plate.

Subsequently, in the course of experiments with a large number of other substances, Schmidt and Madame Curie independently found that matter containing the chemical element thorium also produced spontaneously rays similar to those due to uranium.

On examining a number of minerals in their natural states as they came from the mines Madame Curie discovered that several of them (for instance, pitchblende, from Austria, and carnotite) produced two or three times as much radiation as uranium or thorium could produce alone. Following out the idea that this excess of radiation must be due to some unknown substance or substances in the minerals, Monsieur and Madame Curie carried on a long series of analyses, which led to the isolation of several new chemical elements, to one of which they gave the name of radium. These new elements are present in the minerals in excessively minute quantities, and, consequently, they must have an enormous radiating power.

Radium has been found to be widely distributed throughout the earth's crust, and the ocean even contains a certain amount of it. It is mined commercially in many localities, but most of the radium used in America comes from carnotite obtained from mines in Colorado and

Utah. Tons of ore have to be treated in order to accumulate a single gram of radium, and the process of extraction requires tons of chemical reagents. The high price of radium salts is due to the cost of these reagents and of the labor employed.

In the course of researches on these peculiar radiations Rutherford found that thorium gave off continuously a gas that also possessed the power of emitting similar types of rays; and later Dorn observed that radium, too, emitted a gas possessing the same property. At first these gases were called emanations, but more recently the name "niton" has been given to radium emanation.

A long series of subsequent researches by Monsieur and Madame Curie, Rutherford, and others has brought to light more than thirty different chemical elements, each of which continuously and spontaneously radiates these extraordinary rays.

By definition the property by virtue of which substances emit these rays is called "radio-activity," and those substances that emit the rays are called "radio-active substances."

The importance of these discoveries in the treatment of disease comes from the fact that the rays produce marked physiologic effects when they pass through tissues. Walkhoff in 1900 first observed that they produce burns similar to x-ray burns, and his results were confirmed by Giesel, Curie and Becquerel, and others. The effect, in the main, is a destructive one, repair taking place very slowly.

Immediately after the discovery of the physiologic action of the rays Danlos employed the rays from radium salts in the treatment of certain skin diseases. Thereafter radium therapy grew as fast as the salts could be obtained.

Some years later Wickham, Degrais, Dominici, and others made marked scientific improvements in technic, introducing among other things the principles of filtration and cross-fire, which will be explained below.

The idea of using the gas, niton, instead of the radium seems to have occurred to several persons at about the same time. In 1909 one of us began working on certain improvements in the methods of extracting and purifying niton for the purpose of constructing a practical machine for every-day use. In 1912, shortly after its foundation, the Radium Institute of London gave numerous treatments with relatively large amounts of niton in various kinds of containers.

In 1913 one of us introduced methods of treating certain types of cases by means of other active substances, called radium A, B, C, or the deposited activity (see below); and also, a method of obtaining very long exposures to very weak radiation by inserting small tubes containing minute quantities of niton into the tumor tissues and leaving them there for days or weeks at a time.

On account of the greater safety of employing niton and radium A, B, C, instead of the radium itself, and also because greater flexibility can be obtained, all of the institutions in this country and most of those abroad which possess a gram of radium or more use these newer methods.

During the last ten or twelve years in the central part of Europe many treatments of various diseases have been given by means of the active substances associated with thorium (mesothorium, etc.). The methods employed do not differ essentially from those used in radium therapy. The details of preparing the applicators, however, are in some instances not quite the same.

Much has been written about the curative properties of niton and other active substances contained in mineral spring waters, etc. Often drinking-waters and water for baths have been made active by introducing into them small quantities of the above-mentioned substances. No doubt these generally contain small amounts of the active substances, but usually the substances are present in such minute quantities that it is difficult to believe that the rays from them can have any appreciable physiologic effect whatsoever. The same may be said of some of the devices designed for the inhalation of air or oxygen containing small quantities of niton.

Groups or Families of Radio-active Substances.—During a long series of researches by the Curies, Rutherford, and others, extending over twenty years, the following properties and characteristics of the radio-active substances have been discovered. Space does not permit a detailed description of the experiments, but only a brief résumé of some of the results obtained.

Radium and the other radio-active substances are chemical elements in the sense in which these words are used in chemistry, *i. e.*, so far as chemical reactions, etc., are concerned. Unlike most chemical elements, however, each of them spontaneously transforms itself at a measurable rate into one of the other elements. Thus radium, a metal, transforms itself into niton, an inert gas. The rate of this transformation is so slow, however, that about 1750 years will be required for half of a given quantity of radium to disappear. Niton transforms itself into a third element, called radium A, which adheres to any and every body that comes in contact with the niton, including the walls of the vessel containing it. The rate of transformation in this case is much more rapid, only 3.85 days being required for half of a given quantity of niton to disappear. Further, radium A transforms itself into a fourth element, radium B; and radium B, into radium C, etc. The rates of these transformations are such that half of radium A disappears in three minutes; half of radium B, in 26.7 minutes, and half of radium C, in 19.5 minutes.

The five radio-active elements mentioned above are the most important of all from the point of view of radiotherapy. The books referred to at the end of this article contain tables of all the known radio-active elements.

Types of Rays.—In analyzing the radiation that comes from radio-active substances four different types of rays have been recognized, namely, the α-, β-, γ-, and δ-rays.

The α-rays consist of atoms of the chemical element, helium, charged with positive electricity, and projected from the radio-active substance with great velocity. The mechanism of the production of the radia-

tion appears to be as follows: An atom of radium (for example) explodes and expels from itself an α-particle (*i. e.*, a charged atom of helium) with a speed of 1.50×10^9 cm. per second. This enormous speed would carry it more than three times the distance from New York to San Francisco in one second if it could travel that far in a perfect vacuum. The α-particle, however, is quickly stopped if it passes through a material substance. It travels only a few centimeters through air, for instance, before it is brought to rest.

That which remains of the radium atom after the expulsion of the helium atom forms an atom of niton. At a later instant of time the niton atom explodes again, transforming itself into an atom of radium A, and at the same time expelling another α-particle exactly like the first one, but with a somewhat greater velocity, namely, 1.62×10^9 cm. per second. During the explosion which transforms radium A into radium B a third α-particle is expelled, this time with a velocity of 1.69×10^9 cm. per second.

The β-rays consist of small particles, called electrons. Benjamin Franklin suggested that electricity probably had an atomic structure, and modern science has demonstrated that he was right. The electrons are, in reality, atoms of electricity. They have a very small mass, 1850 times as small as the mass of the hydrogen atom. Their electric charge is half that of the α-particle, but of opposite sign, being negative instead of positive.

During some but not all of the transformations of one radio-active element into another β-particles are expelled with velocities often ten times as great as those of the α-rays. The three successive explosions mentioned above do not produce β-rays. The explosion which transforms radium B into radium C, however, expels a β-particle of high velocity, but no α-particle.

The explosions that follow when radium C breaks up are more complicated. These expel both α- and β-particles, the α-particles with a velocity of 1.92×10^9 cm. per second, and the β-particles with velocities some of which almost equal that of light itself, namely, 3×10^{10} cm. per second.

The very high speeds of the β-particles cause them to penetrate material bodies much further than the α-particles. Whereas about $\frac{2}{10}$ millimeter of tissue stops the α-particles, the swiftest β-particles traverse several centimeters of tissue before coming to rest.

In the γ-rays we have a kind of radiation totally different from the α- and β-rays. The γ-rays consist of waves traveling through space, and not of projected atoms. The chief characteristic of wave radiation is the wave length, or distance between successive waves. As far as known at present no fundamental difference exists between ordinary light, x-rays, and γ-rays except in the lengths of the waves, and most of the various effects produced by the different kinds of rays may be ascribed to differences in wave lengths. Wave lengths are usually measured in terms of what are called angströms, the angström being a length equal to 10^{-8} cm. The lengths of ordinary light waves lie between

7000 and 3500 angströms; those of ultraviolet light, between 3500 and 220 angströms, and those of x-rays, between 15 and $\frac{1}{10}$ angström. The lengths of the γ-rays overlap those of x-rays and extend to still smaller values, the lengths of the shortest of them never having been measured.

From the point of view of therapy the chief difference between x-rays and γ-rays lies in their penetrating powers; γ-rays are more penetrating than x-rays. A ray that is half as long as another ray penetrates eight times as far through tissues.

All of the explosions that mark the transformation of one radio-active element into another produce γ-rays, but those accompanying the breaking up of radium B, and especially of radium C, produce the most intense and the most penetrating γ-radiation.

The δ-rays are of a secondary nature, being produced whenever rays of the α, β, or γ types strike material bodies of any kind. Their importance in radiotherapy lies in the fact that, being for the most part easily absorbed, they produce irritating and undesirable effects in the skin, etc.; especially if they come from heavy metals such as lead. If applicators made of such metals are used, great care must be taken to suppress the δ-rays by interposing sheets of lighter metals and rubber, etc.

Although the α-rays carry 90 per cent. of the energy of the radiation, they are of relatively small importance in radiotherapy. Most applicators containing the radio-active substances are constructed in such a way as to absorb the α-rays before they can reach the tissues to be radiated, and even if the α-rays did reach the tissues they would not penetrate beyond their most superficial layers. In certain methods of treatment, however, in which the radio-active substances (in solution or otherwise) are injected into the tissues or into the blood-stream the α-rays play an important part, for in these cases the radio-active substances come into direct mechanical contact with the tissues to be radiated.

The most important rays in therapy are the β- and γ-rays, and especially those coming from the breaking up of radium B and radium C, for these rays are the most intense and the most penetrating.

Methods of Treatment with Radium Itself.—Space does not permit a detailed description of all the methods of employing radio-active substances in the treatment of disease that have been suggested or tried, but only those that have proved themselves to be of value.

All applicators containing radium itself must be constructed in such a way as to retain the gas, niton; for, if the niton escapes, very little radium A, B, C will be produced in the applicator, and, as stated above, the most efficient radiation comes from radium B and C.

After a gas-tight applicator containing radium has been freshly prepared the niton and radium A, B, C accumulate in it, being produced from the radium at a constant rate. At the expiration of about one month enough niton will have accumulated to make the rate at which it and radium A, B, C disappear approximately equal to that at which the radium produces them, and thereafter the amounts of niton and

radium A, B, C present remain practically constant. In this state the niton and radium A, B, C are said to be in equilibrium with the radium from which they came. An applicator containing radium and the equilibrium amounts of niton and radium A, B, C produces a constant radiation, and this constancy of radiation adds greatly to the convenience of making treatments. It is, however, by no means essential if care be exercised in measuring the activity of the applicators.

The amount of niton in equilibrium with 1 gram of radium is called a curie of niton, and that in equilibrium with 1 milligram of radium is called a millicurie of niton, etc. We also speak of millicuries of radium A, B, C, etc.

In the early history of radiotherapy glass or metal tubes containing one of the salts of radium were used for treatments. These possess certain disadvantages, however, for the walls of the tubes if thick enough properly to protect the radium against loss by breakage, absorb a considerable amount of the radiation that should be employed in certain kinds of cases. Further, in treating lesions covering considerable areas better results can be obtained by distributing the radiation more uniformly over them.

To overcome these disadvantages Wickham and Degrais employed applicators in which the radium salt, mixed with a kind of paste, was fastened uniformly on the surface of metal plates. These plates were of various sizes and shapes, and, owing to its small thickness, the paste absorbed very little of the radiation. The paste containing the radium was also fastened on the surfaces of metal rods for treating lesions on the walls of cavities, etc.

Very fine sharp-pointed metal tubes containing small amounts of exceedingly pure radium salt have been used to insert the source of the rays into the tumors themselves.

Tubes and applicators containing radium itself may be used effectively, and are so used by physicians and institutions that have not a large enough scientific staff to operate the safer and more flexible methods described below, in which niton and radium A, B, C are employed.

Methods of Treatment with Niton and Radium A, B, C.—On account of the danger of loss by theft, carelessness, the wearing away of radium applicators, etc., and on account of the greater flexibility and power of concentrating the source of the rays into a very small space and placing it accurately at a given point possessed by the newer methods, nearly all of the hospitals and clinics, having at their disposition 1 gram or more of radium employ niton and radium A, B, C instead of radium itself in giving treatments.

Since, as stated above, the rays that are effective in radiotherapy do not come from the radium, but from radium B, C, evidently by extracting the niton from the radium, placing it in any desired container, and allowing it to transform itself into radium A, B, C, we can obtain a great variety of applicators that may be used as sources of radiation.

In order to use these methods it is necessary to install a practical and efficient machine for collecting and purifying the niton. Most of

the institutions in Europe employ liquid air for this purpose, but in America, with one exception, all use the apparatus described by one of us in the Boston Medical and Surgical Journal for December, 1917. The general principles of this machine had been employed by Ramsay and Soddy, Rutherford and Debierne in some of their most important researches.

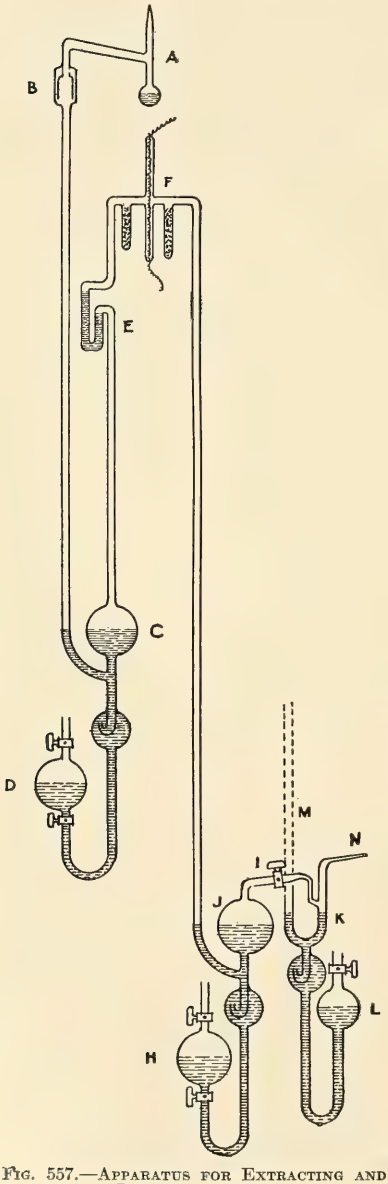

FIG. 557.—APPARATUS FOR EXTRACTING AND PURIFYING NITON.

Figure 557 represents the arrangement of the glass tubes and reservoirs. The bulb *A* contains the radium (which should be in the form of the bromid or chlorid salt) dissolved in water. The niton escapes from the solution, but along with it comes a relatively large volume of oxygen and hydrogen; for the rays from the radio-active substances decompose the water into its chemical elements. The oxygen and hydrogen must be removed if the niton is to be compressed into a small volume. The parts of the apparatus (*C*, *D*, *E*, *F*) accomplish this. Raising and lowering the mercury in the bulbs and tubes (*C*, *D*, *E*) transfers the mixture of gases containing the niton into the tubes *F*, where a wire covered with copper oxid, and heated red hot by an electric current, recombines the oxygen and hydrogen, forming water vapor. One of the side tubes (*F*) contains P_2O_5, which absorbs the water vapor. After the purification the system of mercury pumps (*G*, *H*, *I*, *K*, *L*) transfers the niton through the tube *M* and compresses it into any desired container that may be fastened to *M*.

As a general rule the process of extracting and purifying the niton is carried through once a day, the amount of niton that has accumulated during the previous twenty-four hours being obtained. The process may be repeated oftener, however, if large quantities in a single tube are not required.

Usually the niton is compressed into small glass spheres 1 or 2 millimeters in diameter, or into small glass tubes several millimeters long and less than $\frac{1}{2}$ millimeter in diameter. These are placed inside small tubes the thickness and material of which depends upon the character of the treatment it is desired to give.

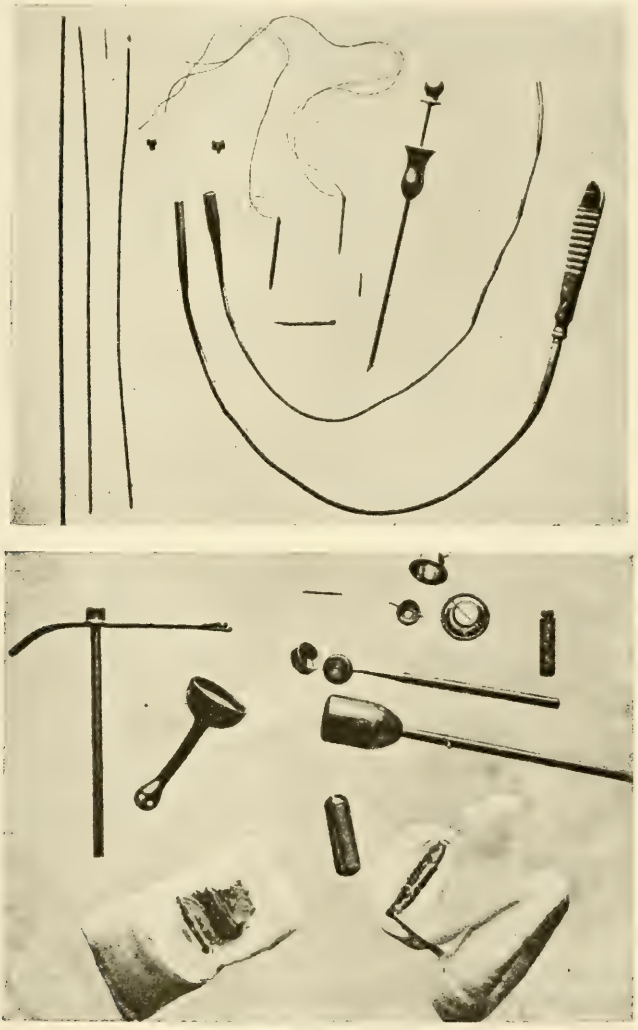

Fig. 558.—Radio-active Applicators.

Figure 558 represents a few of the types of applicators employed.

If the bulb (Fig. 557, *A*) contains a gram of radium, about 150 millicuries of niton should be obtained each day. The niton, however, breaks up, about one-sixth disappearing every twenty-four hours. The machine replenishes the supply at intervals, however, and after a while

one has on hand a number of tubes containing different amounts of niton.

The most effective method of treating certain tumors appears to be the insertion into them through a trocar of exceedingly small glass tubes containing a few millicuries of niton, or even as small a quantity of niton as a fraction of 1 millicurie. The tube remains in place until most of the niton has disappeared, and this subjects the tumor tissue to a very prolonged radiation lasting for days or weeks. The method possesses the advantage of utilizing most of the easily absorbed β-rays, thus localizing the destructive effect. Normal tissues at a distance of 2 cm. or more from one of these tubes appear to be able to withstand indefinitely the very weak radiation that reaches them.

Instead of employing the niton we may use the radium A, B, C alone. Radium A, B, C deposit themselves on everything that the niton comes in contact with. By placing a sheet of metal, for instance, in a glass tube, sealing it to the pumps at *M* (Fig. 557), and compressing the niton into it, we may obtain a deposit of radium A, B, C on the surface of the metal. This activated metal sheet may be used for treatment in certain kinds of cases, but only in those where a short exposure is required, for the radium A, B, C disappears after a few hours.

By depositing radium A, B, C on grains of salt and then dissolving the salt in distilled water highly radio-active salt solutions may be obtained for injection into the tissues or the blood-stream. Such injections have been made in cases of myelogenous and lymphatic leukemia. A decrease in the white cell count, a reduction in the size of the spleen, and a certain destruction of the bone-marrow follows the injection. Care must be taken not to inject too active a solution. Doses of over 100 millicuries are dangerous. A great advantage of injecting radium A, B, C instead of niton or radium lies in the fact that the radiation cannot last more than a few hours, as the radium A, B, C disappears within that time.

The Principles of Filtration, Cross-fire, and Inverse Square.—In treating a tumor the whole of which lies on and near the surface (superficial types of epidermoid carcinoma for instance) small quantities of the radio-active substances should be employed during short exposures, and in such a manner as to utilize a large part of the easily absorbed β-rays. For these easily absorbed rays do not penetrate far into the healthy tissues lying below the tumor and the weak penetrating rays coming from the small amounts of the radio-active substances that do reach the healthy tissues pass through without producing much effect.

If, however, the tumor possesses some depth or lies below the skin (*e. g.*, malignant lymphoma, Hodgkin's disease, etc.) the easily absorbed rays should be cut off by interposing sheets of metal between the radio-active substances and the tissues, for these rays would not reach the deeper lying tumor tissues, and might produce excessive destruction of the more superficial layers of tissue. The idea of cutting off the easily absorbed rays by means of sheets of solid substances and allowing the

more penetrating rays to filter through is known as the principle of filtration.

Destruction of superficial tissues in cases where this is to be avoided may be very much reduced by placing the radio-active applicators in several different positions about the tumor, and radiating it from different angles. With this distribution of applicators all the rays that reach the tumor do not pass through the same areas of superficial tissues, and the destructive effects in them are, therefore, diminished. The idea of allowing the rays coming from different directions to cross each other in the tumor is called the principle of cross-fire.

The rapidity with which the radiation diminishes at points further and further removed from the source is often underestimated. The intensity of radiation from a point source diminishes as the square of the distance from that source, even though there may be no appreciable absorption of the rays by the matter through which they pass. This inverse square law has an important bearing on the technic of radiotherapy. For example, in radiating the spleen in leukemia cases the applicator should be raised and held at a considerable distance above the skin, for by so doing the amount of radiation absorbed by the skin is reduced as compared with that absorbed in the spleen lying some distance below it.

The importance of knowing the quantity of the radiation coming from the radio-active applicators as well as the quality of the rays cannot be exaggerated. Space does not permit a description of the technical details in the construction of the various instruments used in measuring the radio-activity of applicators. Suffice it to say that all important methods of measuring the intensity of the rays have as their basic principle what is called the ionization of a gas. When the rays pass through a gas they make the gas a conductor of electricity to a small extent, *i. e.*, the gas is said to be ionized. The magnitude of the electric current that can be forced through a given volume of a gas when the rays pass through it is taken to be a measure of the intensity of the radiation and of the quantity of the radio-active substance in the applicator. It is convenient in practice to have three measuring instruments: (*a*) A standard instrument for accurately measuring the radio-activity, (*b*) a less sensitive instrument to be used by the clinician for estimating the strength of the tubes, etc., and (*c*) a rough instrument for detecting the presence of radio-active tubes if they are lost, etc.

The question as to the relative importance of the quantity of the radio-active substance in the applicator and the length of time during which the lesion is exposed to the rays has been the subject of some discussion. There does not seem to be any method of estimating the magnitude of the effect produced on tissues by the rays that is sufficiently accurate to detect the difference between 100 millicuries acting for one hour and 50 millicuries applied in the same way for two hours. If, however, the time and intensity factors are changed in a much larger ratio, as, for example, in the prolonged exposures to weak radiation mentioned above, there appears to be a marked change in the differential

effects produced on different kinds of tissues. In the prolonged exposures the destructive effects on certain kinds of tumor tissues seem to be more marked, as compared with the destructive effects on normal tissues, than in the shorter exposures to more intense rays.

In general, therefore, both the length of the exposure and the number of millicuries should be taken into account and recorded, and not simply the number of "millicurie-hours."

In Europe the dosage is sometimes expressed in terms of the amount of "niton destroyed" during the treatment. Evidently the total radiation passing through the tissues, regardless of the time of exposure, is proportional, the filtration, etc., remaining the same, to the amount of niton destroyed (for each atom of the radio-active substance that disappears produces a definite amount of radiation), and therefore the quantity of niton destroyed may be taken as the measure of the dosage, just as well as the number of millicurie-hours.

To transform dosages expressed in terms of millicuries destroyed into dosages expressed in terms of millicurie hours we must multiply the former by 133.

Great care should be exercised in handling the radio-active substances. No active applicators should ever be held by the fingers, but always with long forceps. If this precaution is not taken, the fingers soon begin to lose their sense of touch, to be sensitive to heat and cold, to burn (even if severe ulcers do not form), and after long-continued exposure the tough callous keratotic tissue that forms may degenerate into carcinoma similar to *x*-ray carcinoma. All applicators when not in use should be kept behind lead screens several inches thick, and the glass bulb containing the radium together with all the parts of the pumping system that become very radio-active should be installed in a vault with thick walls.

Great importance has been attached to the question whether or not very weak radiation stimulates the growth of tissue. Any injury to the tissues stimulates those processes that lead to the repair of that injury. The destructive action of the rays is no exception to this, although the processes of repair take place very much more slowly than in most other injuries. It has not yet been proved that weak radiation from radio-active substances stimulates the growth of human tissue other than through the processes of repair.

The precise effects produced when rays pass through tissues are not very well understood, and probably will not be until we know much more about the electromechanics of the processes taking place in living organisms than we do at present. Possibly researches on the structure of living tissues, similar to those recently carried on by means of *x*-rays on the structure of various solid bodies, may lead to the solution of some of these exceedingly interesting questions. Perhaps, too, modern theories of the substructure of atoms and the rôle played by the electrons therein may help us to a clearer understanding of the interaction of the groups of atoms that form living cells. As far as we know at present most but not all of the effects produced by rays on cells are confined

to the nuclei, and the nuclei are more vulnerable during mitosis than during the resting stage.

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Part II

RADIOTHERAPY

While it is true that the benefits of radiotherapy have fallen somewhat short of the hopes of the first investigators, a considerable number of diseases have been found to react favorably to radiation, and there is good reason to expect that this list will be increased when larger amounts of radium, more effective methods of application, and a more accurate knowledge of its biologic effects have been secured.

Already treatment by radium is admittedly superior to other methods of treatment in a small but definite group of lesions, and these facts should be recognized in order that patients may obtain the benefits of the form of treatment most efficient in their disease. In general, it may be said that superficial lesions, whether malignant or non-malignant, which involve an increased growth of tissue either of epithelial or connective-tissue origin, are the lesions which yield most readily to the beneficial effects of radiotherapy. Thus for the non-metastasizing epidermoid and basal-cell carcinomata of the external skin, and for the benign hypertrophies commonly recognized as "precancerous" lesions (papillomas, keratoses, and the so-called benign epithelioma), radium has come to be accepted as the treatment of choice. For the metastasizing forms of cancer, such as carcinoma of the lip, tongue, jaw, breast, and uterus, etc., the efficiency of radium treatment is not so manifest. If the disease is recognized in its earliest and most favorable stages, before metastasis has taken place, the local lesion can perhaps be destroyed by radium, but if the disease is already implanted in the regional lymph-nodes, its control by radium is seldom if ever possible.

In the early days of surgery a certain number of cases of carcinoma were undoubtedly cured by purely local excision of the primary focus of the disease without the removal of the regional lymphatics, but the num-

ber of such cases was very small, and the vast majority of cases failed of cure because the disease was already beyond the limits of a local operation. Destruction of the primary focus of cancer by radium must be considered virtually the same as the local excision of the disease.

A "selective" action has been attributed to radium by many writers. By this it is implied that malignant or pathologic tissue exhibits a vulnerability or susceptibility to the influence of radio-activity greater than the surrounding normal tissues of the body. There is abundant evidence that a selective action of this nature *does* exist in the case of certain definite and specific types of pathologic tissue. The tissue of malignant lymphoma, for instance, after exposure to the γ-rays of radium undergoes profound modifications, reaching ultimately to its complete disappearance without material changes in the normal tissues which surround the disease. This action, however, is not so apparent in cancer of squamous-cell or glandular origin when it is situated in the deeper tissues of the body, and in this respect the anticipations of the early investigators that radium would prove a universal cure for cancer have not been justified.

The biologic and pathologic effects of radiation are still under investigation in the laboratories and clinics throughout the world. It has been determined that an immediate change in living tissue occurs when exposed to effects of radiation of sufficient strength, such that the electric conductivity of the tissue is at once diminished. Cells grown in tissue culture and exposed to the effects of radiation undergo morphologic changes which are followed by a cessation of activity, which may be transient or permanent according to the dose. There is reason to suppose that the effects of radiation differ according to the penetration of the rays and according to the tissue, or even the portion of the individual cell in which the radiation is absorbed, and there is good reason to believe that phenomena of retardation or destruction of growth depend in a considerable degree upon the absorption of the rays in the substance of the nucleus of the cell. Experiment has shown, as in the case of so many drugs or agents which are capable of injurious or destructive action upon tissue, that a small dose of radiation may be followed by stimulation, and that a temporary arrest of growth may be followed by increased activity such as to surpass the rapidity of growth in the unradiated control. There is, in fact, much discussion at the present time in regard to this stimulating action of small doses of radiation. The normal tissues surrounding the lesion seem to show stimulation in many instances. Such a phenomenon, however, exists independent of radiation, and a certain amount of cell proliferation takes place in the normal body tissues surrounding almost every pathologic process, whether inflammatory or tumor growth. This is a normal reaction of living tissue associated with the conservative phenomenon of repair. The presence of the abnormal tissue in the body excites upon the surrounding normal tissue a series of changes destined to surround or to extrude the damaged tissues and repair the defect. There is reason to believe that this phenomenon is enhanced by radiation. There are numerous

observers, however, who maintain that cancer tissue may be stimulated in its growth by a dosage of radiation too small to effect its destruction, and the claim has actually been made that long-continued exposure to minute doses of radiation may actually produce proliferation of cells resembling cancer.

The changes which occur when a superficial epidermoid cancer of the face is exposed to radium radiations are as follows: The exposure produces no immediate symptoms whatever. At the end of forty-eight hours slight reddening of the skin over the area exposed usually takes place, increasing in depth of color for about a week. At that time a definite crust is formed, beyond which the skin shows a degree of active hyperemia. If this crust is removed, a moist surface is exposed, made up of the corium and deeper cells of the skin. The line of demarcation at the limits of the exposure is sharp and well defined. At the end of another week beneath the crust of exudate a yellowish adherent slough is found, composed of fibrin and necrotic tissues. The hyperemia about this slough is more distinct, and if the region is one well supplied with sensory nerves the lesion may be painful. As time goes on the fibrin slough separates, leaving a clean surface of granulation tissue, and the defect diminishes in size. At the end of four or five weeks the lesion is healed, the scar is soft and insensitive, and but little depressed below the level of the surrounding skin. The superficial pathologic tissue has disappeared and the disease is cured. As time goes on the color of the scar approximates that of the surrounding skin.

The most important application of radium therapy to disease has been in the treatment of cancer. The destructive effect of radium can be demonstrated in practically every case of cancer where the disease can be made accessible to effective radiation. Cancer causes death, however, in the majority of cases not by its external manifestations, but by its development in the internal organs in situations where some vital function is interfered with by its presence. In these situations the effective application of radium therapy is almost always impossible. For this reason radium cannot be expected to cure advanced cases of cancer with multiple extensions to the internal organs. Where the disease is recognized early, while still in its local stage, and when the location is such that the disease is readily accessible to the direct action of radium rays, the diseased tissues can often be destroyed. Even when the disease is beyond the possibility of cure, great benefit to the individual may be obtained in many cases by the application of radium to the local lesion for palliative treatment. In such cases the distress caused by the local disease may be much diminished, although the internal and more remote progress is not markedly affected.

One of the common situations of cancer is upon the external skin, especially over the exposed portions of the body—the hands and face. Two types of superficial cancer of the skin are recognized: epidermoid or squamous-cell cancer and basal-cell cancer or rodent ulcer. Both of these types of disease are superficial in their origin and slow to produce metastasis. They are, however, locally invasive, and extend by infiltra-

tion through all the tissues with which they come in contact. They are thus of a low degree of malignancy, and are, therefore, suited to treatment by radium. This is one of the fields in which radium has established itself as the method of treatment of choice. In many situations, as about the eyelids, the scar left after the destruction of the disease by radium produces less deformity and is far less conspicuous than that which would result from adequate surgical excision. Smaller lesions of either the squamous-celled or basal-celled type yield with almost absolute certainty to radiation, and a single exposure of 100 millicuries for a period of one or two hours at a distance of 1 cm. is often sufficient to remove all evidence of the disease. A smaller dose of 30 to 40 millicuries applied directly in a steel tube will accomplish the same result.

Cases of squamous-cell carcinoma with metastases in the regional lymph-nodes are, in our experience, not curable by radium alone, and surgical removal by block dissection of the regional lymph-nodes is necessary to destroy the disease. In these cases the destruction of the local lesion may be accomplished by radiation or by operation, according to the situation and extent of the local tumor.

Cases of basal-cell cancer, or rodent ulcer, are readily destroyed by treatment in their early stages. When infiltration of the surrounding tissues has occurred, however, and especially when the process involves bone, radium treatment is often ineffective. Such cases when of long duration and of wide extent appear to be influenced but little if at all by the most massive doses of radium that can be applied.

Cancer of the buccal mucous membranes—the lip, cheek, tongue, and jaw—belong to the metastasizing forms of cancer, and, as such, are suited to radium treatment only for the destruction of the local lesion. If the disease is to be cured treatment must be given before the regional lymph-nodes are involved, or the use of radium must be supplemented by surgical dissection of the neck to remove the disease of the lymph-nodes.

In cases of cancer of the lip the extension to the lymph-nodes occurs somewhat less rapidly than in cases of cancer of the tongue and jaw. The moment at which this extension occurs, however, can never be determined, and in any case of established cancer of the lip the probability that regional metastasis already exists must be considered. Since the lip is a situation in which the surgical removal of local disease is an operation of minor severity, and adds but little to the necessary operation for the neck dissection, surgery is to be preferred to radium in the treatment of the majority of cases. Where surgical operation is contraindicated, however, as by constitutional disease, radium can be used with propriety. If the disease is in the lymphatics of the neck, however, a cure by radiation is not to be expected.

The radical cure of cancer of the jaw and tongue by surgical measures is a matter of far greater severity and, unfortunately, of much less success than the operative treatment of cancer of the lip. Metastasis occurs early in these cases, and the dissection of the neck is therefore imperative in cases where it can be performed. Where the disease is

extensive, however, radium treatment of the local lesion may properly be applied. In some of these cases a combination of excision, cauterization, and radium therapy has yielded good results. It is in cases of this character that the implantation method of radium therapy may be used, and tubes of from 2 to 6 millicuries can be embedded in the tumor to bring about its local destruction in cases where no surgical measures could be used. When the disease has once extended to the cervical lymph-nodes, however, a permanent and radical cure of the disease by radium is not to be anticipated.

An important field for radium therapy is provided by cases of cancer of the nasal mucous membranes and the accessory sinuses. The radical surgical treatment of cancer in these regions is admittedly unsatisfactory. This is due usually to the difficulty of obtaining a complete excision of the disease without contamination of the wound and implantation of cancer cells, with the inevitable subsequent local recurrence. Metastases from cancer of nasal mucous membranes are notably late in their development. For these reasons radium promises a field of usefulness. Small and accessible lesions may be destroyed by the direct exposure of the lesion to radium rays. In other cases the implantation method has proved effective, and finally in the more extensive cases of disease the combination of primary operation with local excision of the tumor, followed by radiation by implantation, has given good results. In a number of cases of this character operations involving resection of the upper jaw and exposure of the antrum or nasal passages to direct inspection have permitted observation of the tumor area for a period of months, until the success of the local destruction was determined. The facial defect is then closed by a plastic operation.

Cancer of the esophagus is one of the diseases in which much was hoped of radium therapy. Unfortunately, these hopes have not been realized. It is possible that cancer of the esophagus is rarely recognized at a stage so early that metastasis or direct extension to the surrounding tissues has not occurred. As a palliative mesaure radium is capable of destroying some of the obstructing tissue and permitting greater freedom of swallowing. The application of radium in cases of cancer of the esophagus is readily accomplished by special instruments, but the results in our experience have shown only palliative benefit.

Cancer of the stomach and intestines, metastatic cancer of the lung, liver, and retroperitoneal lymph-nodes have proved refractory to radium treatment. No material benefit is to be expected in these advanced cases. The disease is not readily accessible to radium. Metastatic growths are usually of wide extent, and in this region of the body large doses of radium are attended by serious constitutional symptoms, consisting of malaise, nausea, and epigastric and lumbar pain. These symptoms may come on during the application of the radium, and for a period of twenty-four to forty-eight hours afterward. They are similar to the effects of heavy *x*-ray exposures, and investigations are in progress in regard to the production of these symptoms. In addition to the

constitutional changes profound changes in the blood occur after heavy radium treatments by which the white cells of the blood are markedly diminished in number. The polynuclear leukocytes as well as the lymphocytes are both diminished in number and occasional temporary variations occur in their relative proportions. The blood-platelets are increased, and the white cells show a change in the granules in the protoplasm.

The treatment of cancer of the rectum by radium has been restricted chiefly to inoperable and recurrenct cases, and the results have been something of a disappointment, although alleviation of bleeding and offensive discharge has been obtained. The most marked results in the way of local destruction of tissue are obtained by the insertion method—tubes of 4 to 6 millicuries being inserted directly into and around the tumor mass. A colostomy is usually necessary before active treatment of this nature can be begun on account of the sensitiveness to radiation of the rectal mucosa and the distressing tenesmus brought on by strong applications in this region. It is possible that early lesions may be destroyed by radium, but radical operative treatment in early cases is considered the safest procedure in the best surgical clinics.

Few cases of cancer of the breast are suited to radium treatment. The disease covers so wide a territory in its regional metastases, and extends so early to the lymph-nodes of the axillary and supraclavicular regions and to the mediastinum, that little can be done with radium. Local and superficial skin metastases after operation can, indeed, be destroyed with radium, but upon the deeper deposits of the disease no material effects are to be expected. It is our custom to advise *x*-ray in preference to radium for the treatment of inoperable or recurrent breast cancer, and under massive doses of *x*-ray retardation of growth, shrinking of enlarged lymph-nodes, and relief of pain and of discharge (in ulcerated cases) have repeatedly been observed, although the disease continues in the deeper areas of metastatic growth.

Cancer of the thyroid varies somewhat in virulence. Some tumors of the adenocarcinoma type spread with great rapidity, while others follow an extremely chronic course. Radium appears to aid in retarding the growth of tumors of the latter type, and definite amelioration of symptoms, especially those due to obstruction of the air-passages, have been observed in certain cases.

In the field of genito-urinary surgery radium has proved a valuable addition to the resources of the surgeon. The radical operative removal of cancer of the prostate or of the bladder involves a serious operative risk, with relatively slight expectation of radical cure. Both of these organs, however, by the cystoscope or by operation can be made accessible to direct radiation, and the full destructive effects of radium may be obtained by surface applications or by insertion. In the case of the prostate operative removal of the gland can be performed, and tubes of niton inserted in the remaining tissues of the suspected region; or the treatment may be carried out by long needles containing niton at their tips, inserted through the perineum, or by insertion of tubes

directly into the prostate through the urethroscope. Young has devised special operating cystoscopes and applicators for intravesical radiotherapy of bladder tumors. When the disease is recognized in its early and local stages vigorous treatment promises good results. It must be borne in mind, however, that a destructive application with the consequent ulcerative lesion of the bladder wall involves severe pain and a definite danger of urinary infection. (A more detailed description of the use of radium in genito-urinary cases is given in Dr. H. H. Young's chapter on the Surgery of the Prostate.)

On account of the appalling frequency of cancer of the cervix of the uterus it is probably one of the forms of cancer which has been most frequently subjected to treatment by radium. As a result of this experience the opinion is gaining ground all over the world that in radium we have an agent capable in many instances of destroying the local manifestations of the disease. Although most of the experience has been obtained upon frankly inoperable or recurrent cases, even under these unfavorable conditions the local and accessible process not infrequently can be destroyed, although the deeper and more remote infiltrating portions of the tumor tissue in the parametrium and in the pelvic lymphatics is probably but little influenced by any radiation now available. It is by the destruction of the superficial local tumor tissue that the marked "palliative" benefit is obtained which gives weeks and months of relative comfort and activity to patients who would otherwise be bedridden and helpless, with offensive discharges and recurring hemorrhages. For these cases alone radium has proved one of the greatest additions to surgical resources.

The radical surgical removal of cancer of the cervix of the uterus is an operation of the greatest magnitude. Elaborated by Wertheim the operation has been widely employed, and yet the number of "cures" remains relatively few, even in the hands of the ablest surgeons. As a fact, the operation is practical only in the earliest cases, and at best is attended by many serious complications and a disappointing percentage of cases of recurrence. In some clinics these facts have already been recognized, and *all* cases of cervical cancer are treated with radium in preference to operation. While this position is not as yet widely accepted in this country, there is reason to believe that it is gaining adherents, and it is possible that the treatment by radium of early and operable cases may come to be the accepted method of dealing with this disease. A full discussion of this subject has recently been published by Janeway, to which the reader is referred.

The tissues of the cervix of the uterus are resistant to radium, and vigorous caustic action may be employed without discomfort. The same anatomic conditions, also, which make complete surgical removal difficult give opportunity for radiation of the affected tissues more effectively than in other portions of the body, for both the cervical canal and the vaginal surface of the cervix can be reached by applicators and the insertion of emanation tubes can readily be performed. The dosage employed varies in different clinics according to the methods of

filtration used. We have employed a dosage up to 160 millicuries for twelve to sixteen hours, repeated in four to five weeks. Janeway uses 300 millicuries for twenty hours in the hope of destroying the tumor tissue in one dose. Others have used even larger amounts, but it would seem that the smaller amounts are sufficient if the application can be made effectively. It must be borne in mind that if the radium is not accurately applied it is capable of producing severe damage to the vaginal mucosa and even fistulous openings in the bladder or rectum. In some clinics the local application is supplemented by external applications of heavily filtered rays of radium or x-ray. The value of these methods has not yet been established. The results of local treatment, however, are beyond dispute.

Adenocarcinoma of the body of the uterus is by no means so common as cancer of the cervix. The spread of the disease to the parametrial tissues is less rapid, and the radical removal of the disease by hysterectomy may be accomplished with less danger of local implantation and recurrence. For these reasons the operative treatment of favorable cases remains the treatment of choice, but when for any reason operative measures are contraindicated, radium may be employed by intrauterine application. The thick fibromuscular wall of the uterus permits the use of the β and γ rays of radium for the destruction of the diseased mucosa without undue damage to the surrounding tissues and organs of the pelvis. The dosage employed should be large, and an effort should be made to bring about a complete destruction of the tumor tissue at the first treatment; 150 millicuries for twelve hours should be sufficient. If the disease has extended beyond its local origin direct applications are impossible and only palliative relief to symptoms is to be expected.

Adenocarcinoma of the ovary is a type of cancer of marked and definite pecularities. The disease arises usually as a papillary tumor within a cyst, although solid adenocarcinoma of the ovary is also found. More than other types of abdominal cancer it has the tendency to form peritoneal implantation metastases, and, as such, it is the most common form of cancerous peritonitis. Even when wide-spread peritoneal involvement exists, vital functions may be little interfered with, and the course of the disease may be very chronic. A small number of these cases have been treated effectively by radium, combined with operation: as much as possible of the tumor is removed, and the remainder, by tube or gauze drainage, is left accessible to the direct exposure of radium tubes by insertion into the drainage opening. In one such case reported by Codman an obviously inoperable tumor was so diminished in size that its surgical removal was made possible, and in the interval between the two operations the widely distributed peritoneal implantations of cancer tissue had entirely disappeared.

Sarcoma in our experience has proved less amenable to treatment by radiation than carcinoma, although reports from other institutions are somewhat more favorable. The disease is usually not so superficial, and there is a tendency to the development of larger masses of tissue. Heavy external dosage of filtered rays accomplishes little, and the

insertion of tubes directly into the tumor tissue has proved the most effective method of destroying the disease. By this method successful results have been obtained in a few instances, although the danger of sepsis and of secondary hemorrhage must be considered. In our experience osteosarcoma has proved to be little influenced by radiation, although certain types which have been reported by competent observers seem to have shown satisfactory results. Melanotic sarcoma has also proved refractory to radiation even by the insertion method, for although superficial areas of tumor tissue may be destroyed, the growth in the deeper organs continues, and no material benefit even of a palliative nature is to be expected.

Reference has been made above to the apparent susceptibility of tissues of lymphoid origin to radiation. This tendency is exemplified particularly in malignant lymphoma, or Hodgkin's disease, and in lymphosarcoma. The large tumor masses of lymphoma tissue in Hodgkin's disease shrink up and practically disappear after exposure to sufficient dosage of the penetrating γ rays of radium. Unfortunately, this effect is usually only temporary, and after weeks or months the glands enlarge again, though rarely to the same extent as before. Shrinkage of the glands may be obtained a second and a third time by continued treatment, and eventually little evidence of gross enlargement of glands may be obtained, but the disease continues in the deeper foci of lymphoid tissue, severe anemia develops, and death ensues, even under the most vigorous treatment that can be given with safety to the patient.

Lymphosarcoma is distinguished from malignant lymphoma or Hodgkin's disease by the fact that the enlarged glands are made up of pure lymphoid cells without the characteristic endothelial trabeculæ and giant cells of the so-called Dorothy Reed type of Hodgkin's disease. These tumors also show a definite susceptibility to radiation, and one that in our experience is more permanent than in the case of the lymphomata of the Hodgkin type.

A certain number of tumors of the lymphosarcoma group originate in organs in which the lymphoid apparatus is predominant, such as the tonsil and the intestine. In these cases also the tissue shows its characteristic susceptibility to radium, especially when direct applications can be made. When, however, the disease has extended to the deeper lymph-nodes it is resistant to radium treatment, as in so many other forms of disease.

Malignant tumors of the glioma, hypernephroma, and teratoma groups have been subjected to treatment with radium with varying results. Some believe that these tumor tissues of embryonic character show definite susceptibility to destruction by radium. A number of observers draw attention to the recognized vulnerability of normal ovarian and testicular cells to the effects of radiation, and trace this same susceptibility in the tumor which arise from these tissues. It is possible that this is true in regard to the primary tumor when such a tumor can be made accessible to direct and vigorous treatment. The majority of cases, however, are presented for treatment with radium

only after metastases in the deeper organs have occurred, and in these cases anything more than palliative treatment is not to be expected.

Among the earliest observations of the effects of radium on tumor growth there were reported instances of its favorable action upon mixed tumors of the parotid gland. These reports have come from many sources, and there is little doubt that favorable results have been observed. This phenomenon, however, is not constant, and in our own experience we have seen a number of parotid tumors which were apparently unaffected by radium treatment.

One of the first diseases to be subjected to radium therapy was chronic splenomyelogenous leukemia, and it was immediately established that a profound and beneficial effect upon the progress of the disease was obtained by radiation of the spleen with the penetrating γ rays. Chronic myelogenous leukemia proves to be more susceptible to improvement than the lymphatic type. Active types of either disease appear to receive little benefit from radium treatment. The blood-picture in splenomyelogenous cases rapidly changes toward, though rarely quite to, normal. The myelocytes, as a rule, persist in a very small percentage even when the total leukocyte count has returned toward normal limits. With the change in the blood-picture a rapid and surprising diminution in the enlargement of the spleen takes place, and the patient returns to a state of relative health and strength. Unfortunately, this marked improvement is never permanent. The symptoms tend to recur even while under continued treatment, and although remissions may be obtained by subsequent radiation the susceptibility to radiation diminishes and the disease progresses to its fatal termination.

The application of radium therapy in leukemia is generally accomplished by the exposure on successive areas over the enlarged spleen of heavily filtered rays of considerable amounts of radium. Doses of 100 to 250 millicuries, with 2 mm. lead filtration and 5 cm. distance for eighteen hours, or of 50 millicuries similarly applied for four hours every day for ten days have been used successfully in our experience, and larger doses have been utilized in other clinics.

Cases of polycythemia and other atypic blood diseases have also been subjected to radium therapy, and with occasional good results, but the reports are as yet inconclusive, and further investigation is necessary before radium therapy can be wisely advocated for these conditions. It is certain, however, that in radium a powerful agent is available with which to produce changes in the organs for the production and destruction of the cellular elements of the blood.

Radium therapy has been employed for almost every known form of non-malignant skin disease, but there are certain definite conditions in which its application is coming to be recognized as the treatment of choice. As a rule these are the lesions characterized by a productive process, whether of the epidermis or the connective tissues. Among these diseases may be listed: psoriasis, keratoses of all types, papillomata, rhinophyma, nevi, and keloid of all varieties. Most of these

diseases yield to short and unfiltered applications of small amounts of radium. Flat surface applicators, such as are sold for dermatologic practice, are of sufficient strength to cause a definite reaction, followed often by the disappearance of the pathologic tissue and its replacement by the soft and inconspicuous scar which is characteristic of this method of treatment. Keloids yield remarkable results when vigorous treatment is employed, but a definite burn of the skin is often necessary if the scar tissue is very thick.

Lupus responds best to a thorough primary curetage, followed by radiation.

Radium has been widely used for the treatment of pruritus of the anus or vulva, and many favorable reports are published of the efficiency of this treatment. In our experience the subjective itching is not always completely controlled, although the eczematous condition of the skin may be markedly improved. Radium has been employed for the destruction of pigmented moles; but it is a far safer measure to employ excision, on account of the possibility of excitation to malignant growth (melanoma) in case the attempted destruction should for any reason be incomplete.

Of the non-malignant diseases of mucous membranes, leukoplakia is one which has most frequently been subjected to radiation. The milky white thickened mucous membrane can be destroyed by radium, but in our experience milder measures (fulguration) produce equally good results with much less inconvenience to the patient. It is, perhaps, not unwise to reserve for radium treatment the cases of more advanced leukoplakia in which thickening of the epithelial tissues has occurred and the danger of carcinoma appears imminent. In such cases active radium therapy is definitely indicated.

In gynecology radiotherapy has found a field of greatest usefulness. The effects of radium upon the ovaries and upon the uterine mucosa, which result according to dosage in the temporary or permanent cessation of menstruation, provide a prompt and simple remedy for the more serious cases of metrorrhagia and intractable cases of disabling dysmenorrhea. The artificial menopause thus produced is accompanied by many of the unpleasant symptoms associated with operative castration, and the employment of intra-uterine applications in such cases must be regarded as a procedure of grave importance and one not to be undertaken without full consideration of the consequences. The introduction into the uterine cavity of 100 millicuries for three hours on the end of a uterine sound will ordinarily suffice to produce a complete cessation of the menstrual function. Larger doses have frequently been employed, and may occasionally be necessary, but it is probable that the minimum dosage which will accomplish the purpose is to be preferred. Only certain types of uterine hemorrhage and dysmenorrhea are suited to treatment by radium, namely, those associated with "uterine insufficiency": chronic endometritis (polypoid, hyperplastic, etc.) and those associated with disturbed ovarian function. Salpingitis and other inflammatory conditions are an absolute contraindication to the use of

radium. In young women this treatment should be employed, of course, only as a last resort.

Great interest has been aroused by the remarkable effects of the intra-uterine treatment of uterine fibroids by radium. Not only is the bleeding diminished or arrested, but the myomatous tissue of the fibroid shrinks and the tumor diminishes rapidly in size. If it were not for the complications which so frequently accompany fibroids of the uterus it would seem that the radium was to be preferred as a more certain and a much safer measure than operation. When any contraindication to operation exists, such as anemia, cardiac or pulmonary disease, radium is certainly the treatment of choice. When evidence of salpingitis or other inflammatory complications exists, however, the use of radium is strongly contraindicated, and where the fibroid is larger than a three-month pregnant uterus, operation is, as a rule, to be preferred.

Hyperplastic, senile, and other forms of endometritis are suitable for treatment by radium. In all such cases, however, a preliminary curetage should be performed in order that material for pathologic examination may be obtained.

Kraurosis vulvæ is amenable to treatment by radium, and should be treated vigorously to bring about the destruction of the hypertrophic areas. Actual cancer of the vulva or clitoris may be destroyed by vigorous local treatment, but the regional lymph-nodes require surgical removal if the attempt is made to obtain a radical cure.

Urethral caruncle is another disease which yields readily to radio-therapy. The vascular tissue is promptly destroyed and the soft scar which takes its place gives to the patient a most grateful relief from pain.

In ophthalmology radium has been employed with success for certain resistant forms of inflammatory disease, as trachoma and "vernal conjunctivitis," as well as for the treatment of tumors of the eye and orbit. Some of the tumors peculiar to this region, as glioma of the retina, are apparently somewhat susceptible to radiation. Direct treatment in the orbit may be employed in prophylaxis against recurrence after operation before the wound is healed, or implantations may be made in suspected areas of tissue. Radiation has also been employed in the treatment of cataract, but this use of radium is still in the experimental stage.

Chronic otosclerosis and other diseases of the ear have been subjected to radium treatment, and more or less favorable reports have been published in certain cases. The benefit obtained, however, is not of marked extent, and the treatment has not come into wide-spread use.

Radium and radio-active substances in dilute solutions have been widely employed both for internal administration and for external application. Some of these solutions are of natural origin, and others are produced artificially by the solution of radium niton in water. These "radio-active" solutions have been advocated for the treatment of hypertension, arteriosclerosis, gout, renal diseases, and other ills, as

well as for the various types of chronic arthritis. Favorable reports have been published from time to time, but it seems probable that the rapid decay of the radio-active solutions, and the infinitely small amounts available by the time the solutions reach the patient, would make their employment of less value for any possible constitutional effect than for their sentimental or psychic benefit.

As a result of this brief review of the practical aspects of radiotherapy, we may say that radium has proved to be a most valuable addition to the resources of medicine and surgery.

1. In the treatment of carcinoma the destructive action of radium rays on cancer tissue is beyond dispute. If the cancer tissue is superficial and not of too great extent it can be locally destroyed.

2. If the disease has already extended by infiltration or by metastasis to the deeper tissues the effects of deep radiation are rarely if ever curative.

3. A differential action of radium on cancer tissue, such that the carcinoma cells are destroyed without any destruction of the stroma or of the surrounding healthy tissues, is still a matter of discussion.

4. The radical cure of cancer demands the removal or destruction of the local point of origin of the disease, *together with the tissues known to be first involved by infiltration or metastasis.*

5. Radium can in some instances produce the local destruction of the primary tumor, but must be supplementeed by operation upon the regional area of metastases if a radical cure is to be obtained in any case where metastasis has taken place.

6. Since radium treatment is not painful and does not confine the patient to a hospital, it can be applied promptly for suspicious but doubtful lesions, when operation would not be justified.

7. In cancer in certain locations, where radical operation has yielded unsatisfactory results, as in cancer of the cervix of the uterus and cancer of the tongue and mouth, the destruction of the local lesion by radium, supplemented in certain cases by the surgical removal of the regional lymphatics, offers advantages which may yet prove superior to purely operative treatment.

8. Tumors other than carcinoma show varying susceptibility to radiotherapy. Certain types of sarcoma, lymphosarcoma, the teratomata, ovarian and testicular tumors, and the mixed tumors of the salivary glands, all appear to be affected favorably by radium when direct application can be made. When deeply placed these effects are not so evident.

9. The non-malignant hypertrophic diseases of the skin and mucous membranes—the keratoses, papillomas, leukoplakia, keloid, and nevi—are favorably influenced by radiotherapy. In many cases a brief and mild treatment definitely destroys the lesion. In some inflammatory conditions also (eczema, lupus) favorable results are obtained. In many other skin diseases radiotherapy has been attempted without conclusive results.

10. In gynecologic practice radium has proved of the greatest value

in the treatment of uterine fibroids, certain types of uterine hemorrhages, dysmenorrhea, endometritis, kraurosis vulvæ, and urethral caruncle.

11. The value of radiotherapy in leukemia and other blood diseases and in malignant lymphoma or Hodgkin's disease is beyond question. Although the benefits are often temporary, the improvement is apparently more marked than with other methods of treatment.

12. The medicinal use of radium and radio-active substances, as in drinking-water, is not yet established on reliable grounds. The amount of radio-activity thus obtained would appear to be of infinitesimal value.

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CHAPTER LV

THE TECHNICAL AND CLINICAL USE OF THE *x*-RAY

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New York

Apparatus.—The announcement of the perfection of the hot cathode tube by Dr. W. D. Coolidge in 1913 was the greatest stimulus that *x*-ray work had received since its discovery. It is possible with this tube to measure accurately the output both as to quantity and quality.

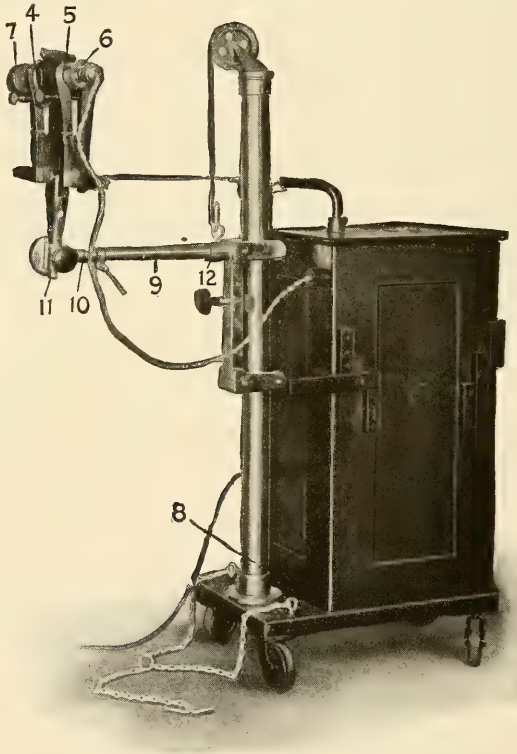


Fig. 559.—United States Army Bedside Unit.

Moreover, a given constant tube potential can be maintained for any length of time that is essential for either treatment or diagnosis. The advance from the original Crookes' tube to the metal cathode tube of Jackson and the gas tube with various types of vacuum regulators has shown progress.

Just prior to the entry of the United States into the war Coolidge, recognizing the needs of our army for light portable equipment, per-

fected an improved type of hot cathode tube known as the "radiator type." The chief virtues of this latest type lay in its small bulb, the extremely fine focal spot, and the ability of the tube to rectify its own current, this last feature eliminating the necessity of heavy exciting apparatus. The perfection of this raditaor type and the light exciting apparatus was complete within two months following our declaration of war and was the basis of practically all of our most useful equipment. The development of this tube has also resulted in a diminution of the size of the step-up transformers previously used, so that the entire equip-

FIG. 560.—COOLIDGE PORTABLE APPARATUS.

ment now needed has been reduced to a fraction of its former size and weight. The newest Coolidge development is a small step-up transformer with the x-ray tube built into the transformer and immersed in the oil of the transformer.

The development of the radiator tube was the basis for the development of the standard U. S. Army Bedside Unit (Fig. 559) which was so generously used in hospital centers with the American Expeditionary Force. Recently Coolidge has perfected a portable apparatus (Fig. 560) which appears to have still further advantages.

The flexibility of the Army Bedside Unit has developed a new field

in bedside observations of patients both by the plate and the fluoroscopic methods. Bedside fluoroscopy is made so simple that little effort on the part of either the patient or the surgeon is required in making fluoroscopic observations in his daily rounds.

The use of bromid papers as a substitute for films or plates is a step in technic that adds to the graphic bedside study, especially of fractures. One of the advantages of using this paper is that a dark room is not required, and the paper can be developed rapidly in some moderately darkened corner near the bedside and can be viewed within a few minutes.

The use of flexible films as a substitute for heavy glass plates has been a welcome innovation. This is especially true since the development of the duplitized film with a sensitive emulsion on both surfaces of the film. A graduation of soft tissue detail, especially in thick parts, is uniformly obtained with these films used with double intensifying screens that was seldom obtained with other methods. Other advantages of the films are lessened lack of bulk, weight, and breakability.

The roentgenogram is a record of the varying densities of normal and pathologic tissues. The value of the roentgenogram is directly in proportion to the accuracy with which the roentgenologist interprets pathologic lesions from these varying densities. The accuracy with which this is done is directly dependent on the breadth and depth of the roentgenologist's knowledge of pathology. In bygone days the pathologist was an artist who could cut the thinnest sections by hand with a razor. The microtome changed that, and he became a scientist who studied the sections and interpreted his findings in terms of disease (pathology). In more recent days the roentgenologist was the artist who, with a gas tube, coil, and some kind of interrupter, could make the clearest roentgenograms. With the advent of the Coolidge tube roentgenography ceased to be an art and became a simple mechanical procedure. Like pathology, roentgenology has become the science of the study of diseased tissues, and the interpretation of the findings in terms of pathology.

Gastro-intestinal Disease.—Two methods have been used for the employment of the *x*-ray in the diagnosis of gastro-intestinal lesions:

(1) The indirect method of symptom complexes.

(2) The direct method of detection of morphologic changes.

The **indirect method of diagnosis by symptom complexes** consists in the enumeration of symptoms, both subjective and objective. Some of the objective symptoms, such as the time required for gastric evacuation, the relation of local points of tenderness to some portion of the stomach or cap, are studied by fluoroscopic examination, and these, combined with the clinical history, physical examination, and gastric analyses, form the data for the compilation of the symptom complex. Various groups of symptoms have been compiled by different observers for the same lesions of the stomach and cap. Holzknecht, Haudek, Schwartz, Kreuzfuchs, and other German and Austrian observers are the chief exponents of this method, which has therefore come to be

known among many workers as the Continental method. Carman was the most ardent advocate of this method in this country, and he compiled a symptom complex to which he gave the name of "Roentgen signs." The great divergency, however, in the symptoms noted by the different observers and compiled by them under the head of "symptom complexes" arouses a feeling of doubt as to their accuracy.

The second method of diagnosis and the one most frequently referred to as the **"direct method"** (sometimes also as the American method) is based on direct observation of morphologic changes, due to pathologic processes in the wall of the stomach or intestine. Such morphologic changes may be detected fluoroscopically, roentgenographically, or by means of serial roentgenography. Each of these distinct methods of determining the direct evidence of pathology is of value, and each has a place in the practice of medicine. The fluoroscopic method of directly detecting pathologic conditions is applicable in clinics, where a large number of patients must be examined in a relatively short time.

Many of the grosser lesions, such as gastric cancers, old or large gastric ulcers with penetrating craters, as well as some of the lesser lesions, can be detected by the fluoroscopic examination; but even the most ardent fluoroscopist never contents himself with fluoroscopy alone; he makes, in addition, a small or a large series of plates. Some objections, of course, may be advanced to this method, and these are that: (1) the patients who suffer but slight pathologic changes may be considered normal, as their lesions pass undetected by fluoroscopic examination, and therefore a series of plates is not made; (2) the fluoroscopic method does not give a sufficient detail to enable the observer to differentiate with sufficient accuracy between cancer, ulcer, and spasm. This can only be really determined by means of serial roentgenography. The ideal diagnostic method is that of serial roentgenography, combined with a fluoroscopic examination, the fluoroscopy for the purpose of arranging the position of the patient so as to better center on relatively small plates, that portion of the tract wherein pathologic changes are suspected.

This method has been successfully employed for ten years; it consists in taking a series of roentgenograms as follows:

10 to 12 plates in the postero-anterior diameter, patient prone.
6 to 8 plates in the oblique diameter, patient prone.
8 to 12 plates in the postero-anterior diameter, patient erect.

The greater accuracy of this method as compared with that of fluoroscopy or single plates is unquestionable, but the increase in cost, both in material and time, renders this measure much more applicable to private practice, where relatively few (perhaps 5 or 6) cases may be studied each day.

Statements subsequently to be made, some of which may appear radical, regarding the accuracy of roentgenologic diagnosis, do not apply to fluoroscopic or to the single-plate method of examination. Such questions as the differential diagnosis between various lesions and the

indications for surgical procedure will be determined only by observations based on serial roentgenography. Such statements only apply to those experienced in the making and interpretation of such serial examinations. Furthermore, any method of *x*-ray examination must be considered as a component part of a complete physical examination and not as a substitute for it. It should be made in co-operation with the clinician. Our own conviction is that the roentgenologist should base his diagnosis solely on the *x*-ray findings and should not be influenced by the clinical history of the patient in his interpretation of the Roentgen evidence. Subsequent to the time at which he has worked out his roentgenologic diagnosis, that is, having interpreted the *x*-ray findings in terms of pathology and recorded them in writing, he should have a consultation with the clinician, and then together they should compare the clinical symptoms and physical findings with the *x*-ray diagnosis. If clinical and roentgenologic diagnosis correspond, well and good; but if not, then each diagnostician should restudy his findings and, if necessary, work out a more complete examination, until, finally, one is able to corroborate the other's diagnosis.

The Accuracy of the *x*-Ray Diagnosis.—Organic lesions of the gastro-intestinal tract, especially those of a character or size that require surgical procedure, may be detected by the method of serial roentgenography, with as great a degree of accuracy as cases of fracture can be diagnosed by stereoscopic radiography.

Pathologic lesions, ulcers, syphilis, tuberculosis, diverticulitis, cancers (and even types of cancer) may be differentiated by serial roentgenography with as great a degree of accuracy as that obtained by the surgeon or the pathologist through macroscopic (not microscopic) examination of the gross specimen, at the operating or at the autopsy table. The indications for surgical procedure, and even the type of surgical procedure destined to be employed, can be determined by a study of the serial roentgenograms. This study, however, should be done by the surgeon and the roentgenologist together.

The *prognostic* value of the method depends on the accuracy of detecting the lesions and one's ability to differentiate one type of lesion from another. The natural history of organic lesions of the gastro-intestinal tract can be observed by this method, and the progress, retrogression, or elimination of the pathologic process as a result of or coincident with medical or surgical treatment may be determined with a remarkable degree of accuracy.

Theoretically, a chapter on gastro-intestinal diagnosis should begin with the teeth, but custom has more or less limited the gastro-intestinal examination to a study of the hollow viscera, filled with an opaque meal or with air.

Esophagus.—The contour of the lumen of the esophagus may be studied either fluoroscopically or roentgenographically because of the fact that this organ is surrounded by aërated lung tissue. Fluoroscopy is especially applicable to this portion of the alimentary tract. Thin fluids pass through this portion of the esophagus so rapidly that various

methods have been devised for retention of the opaque meal in the esophagus. Stewart has used the sausage casing, which is tied at the lower end and then swallowed, afterward being filled with the barium mixture. Hirsch has utilized a gum tragacanth suspension of barium, which he believes causes the barium to adhere to the esophageal wall. We have always employed a thick barium-and-water paste, which completely fills the lumen of the esophagus, especially if the examina-

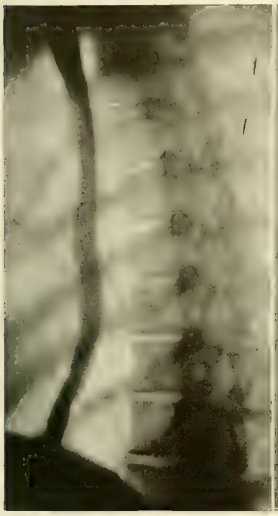


FIG. 561.

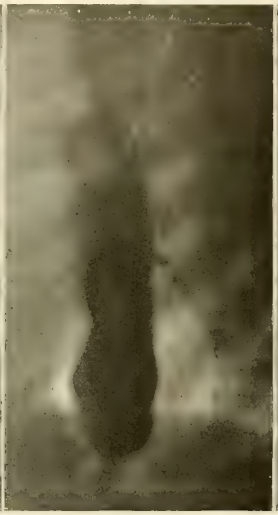


FIG. 562.

FIG. 563.

FIG. 564.

FIG. 561.—NORMAL ESOPHAGUS.
FIG. 562.—CARDIOSPASM OF ESOPHAGUS.
FIG. 563.—CARCINOMA OF ESOPHAGUS.
FIG. 564.—ESOPHAGEAL DIVERTICULUM.

tion is made in the postero-anterior and the oblique directions with the patient prone.

Lesions which can be diagnosed by the combined fluoroscopic and roentgenographic methods are:

(1) Cancer; (2) cardiospasm; (3) diverticulum; (4) non-malignant stricture; (5) varicosities (a condition similar to hemorrhoids) especially when these are at the cardia.

By sufficiently careful study these lesions can be differentiated from each other with a reasonable degree of accuracy. Figures 561–564 show the characteristic roentgenographic findings of the normal and of the commoner lesions.

Fig. 565.

Fig. 566.

Fig. 567.

Fig. 568.

Fig. 565.—Type: Hypertonic.
Fig. 566.—Type: Orthotonic.
Fig. 567.—Type: Hypotonic.
Fig. 568.—Type: Atonic.

Stomach and Cap.—The stomach should be considered as offering the most extensive field for x-ray observation. We will here briefly consider the types of stomach and pathologic lesions which can be diagnosed roentgenographically, the classification of ulcers and of cancer, the indications for surgical procedure, and the natural history of pathologic process, both under medical and after surgical treatment.

The following are the types of stomach that are not involved in organic lesions:

(1) Hypertonic—Fig. 565 (cow horn).
(2) Orthotonic—Fig. 566 (text-book).
(3) Hypotonic—Fig. 567 (fish-hook).
(4) Atonic—Fig. 568 (drain or water-trap).

Each of these types of stomach appears usually to conform to certain types of anatomic figures. The studies of Mills and Soper on this aspect of the subject are classical. Our own view is that the mere fact that the stomach is considerably below the umbilicus in many cases does not constitute gastroptosis. The stomach conforms to the belly in which it is contained, and if it evacuates in normal time, can be considered as a normal stomach. The pathologic types, such as "hour-glass," "leather bottle," etc., will be discussed under the headings of the maladies causing them.

Gastric motor phenomena form a complex rather than a simple progress of the peristalsis pylorusward; the latter resembles that of the heart, in that it goes through a complete series of shapes, and comes back to the original outline, approximately once in twenty seconds, while the heart goes through its cycle in approximately one second. Thus far we have referred to this series of changes as the "gastric cycle," just as we have been taught to speak of that of the heart as the "cardiac cycle." Like the movement of the heart, this cycle is a compound of systole and diastole, and together these constitute the progress of the peristaltic wave from the cardia to the pyloric sphincter. During the systole of each gastric cycle the acid chyme is expelled through the lumen of the sphincter into the reservoir cap where protein digestion proceeds in the small portion of chyme in the cap. It is our belief that alternate acid and alkaline reactions in the duodenum have no effect on this opening and closing of the pyloric sphincter.

The cap is evacuated by a broad peristaltic wave which occurs independently of the gastric peristalsis, and this takes the top off the cap and forces the food through the duodenum in a finger-like mass (Holzknecht); such a mass would be expelled through a duodenal fistula, as observed by Cannon. The broad peristaltic wave may be, and probably is, stimulated by alternating acid and alkaline reaction in the duodenum. A thorough comprehension of the roentgenologic appearance of the stomach during the various phases of the gastric cycle, and the roentgenographic appearance of anatomic anomalies, such as the prepyloric fold and the prepyloric ring, should be obtained before one attempts to undertake to interpret Roentgen findings in pathologic and anatomic terms.

Gastric cancer may be detected by serial roentgenography at any stage at which it can be detected by surgical exploration.

Ewing has classified gastric cancer into the following types:

(1) Adenocarcinoma.
(2) Carcinoma following ulcer.
(3) Gelatinous carcinoma.

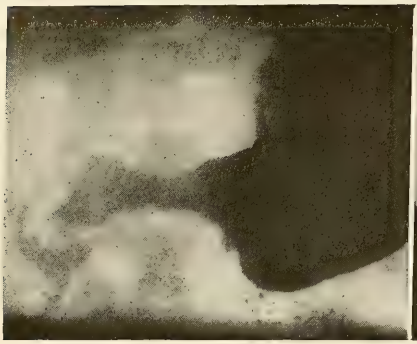


FIG. 569.

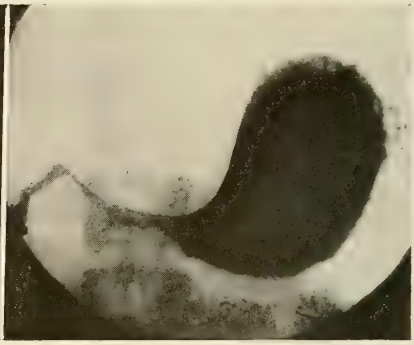


FIG. 570.

FIG. 571.

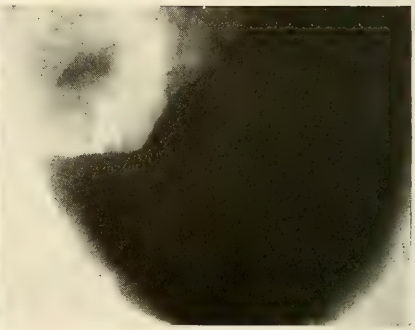


FIG. 572.

FIG. 573.

FIG. 569.—ADENOCARCINOMA.
FIG. 570.—GELATINOUS BULKY CARCINOMA.
FIG. 571.—CARCINOMA SIMPLEX.
FIG. 572.—STENOSING FIBROCARCINOMA.
FIG. 573.—LINITIS PLASTICA (LEATHER BOTTLE).

(4) Carcinoma simplex.
(5) Scirrhous carcinoma.
(6) Sclerosing fibrocarcinoma (linitis plastica).

These various types of gastric carcinoma have characteristic roentgenologic findings which enable us to recognize them with a reasonable degree of accuracy (Figs. 569–573).

The Roentgen indications for surgical procedure in gastric cancer are as varied as the types of neoplasms and the extent and location of the pathologic process. Indications may be either for or against surgical

Fig. 574.

Fig. 575.

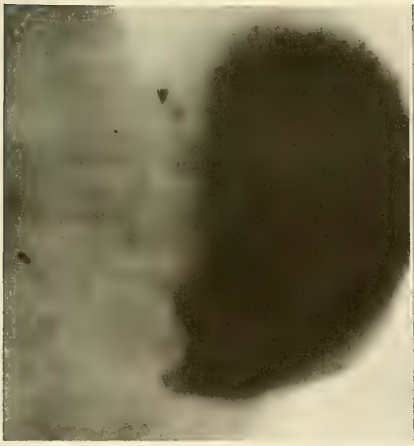


Fig. 576.

Fig. 577.

Fig. 574.—Gastric Cancer—Inoperable—Too Extensive.
Fig. 575.—Gastric Cancer—Inoperable—Operation Unnecessary.
Fig. 576.—Gastric Cancer—Operable for Palliation.
Fig. 577.—Gastric Cancer—Operable for Cure.

procedure. They are divided primarily into two classes: (1) inoperable, (2) operable. Inoperability exists for one of two reasons: (*a*) the growth is found to be so extensive that resection or gastro-enterostomy is impossible (Fig. 574); (*b*) the lesion may be situated so high on the lesser curvature that although a gastro-enterostomy might be performed in the pars pylorica or pars media, it would avail little (Fig. 575).

FIG. 578.

FIG. 579.

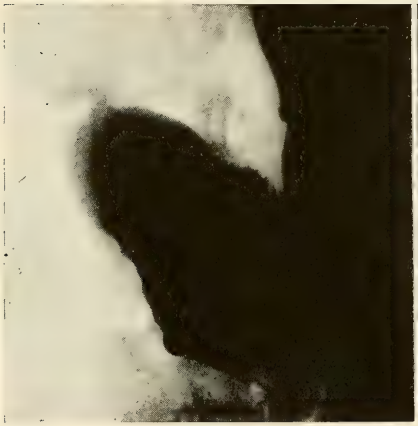


FIG. 580.

FIG. 581.

FIG. 582.

FIG. 583.

Operable cases are classified as follows: (*a*) operable for palliation (Fig. 576); (*b*) operable for cure (Fig. 577). Close co-operation between the surgeon and the roentgenologist will facilitate the determination of these indications. The roentgenologic study of postoperative cases of cancer aids one in deciding whether the desired operative end-results have been obtained.

Gastric Ulcer.—Diagnosis of this lesion is based on morphologic changes in the wall of the stomach. The *x*-ray findings vary greatly according to the type of ulcer. The following types of ulcer may be recognized:

(1) Penetrating—Fig. 578; (2) burrowing—Fig. 579; (3) submucosal crater—Fig. 580; (4) mucosal erosions—Fig. 581; (5) hour-glass deformities from contractions—Fig. 582; (6) florid—Fig. 583; (7) syphilis.

Postpyloric Ulcer.—The term "postpyloric ulcer" is applied to those ulcers which occur in that dilated portion of the tract just beyond the pyloric sphincter, called the cap because of its shape and the manner in which it sits on the pyloric end of the stomach. Adopting the suggestion of Dr. Tower, of the New York Museum of Natural History, this portion of the duodenum has been called the pilleus ventriculi. In previous communications we have given reason for considering that this region is not duodenum, and therefore the term "postpyloric ulcer" is used instead of duodenal ulcer. Ulcers occurring in the horizontal and descending duodenum would be true duodenal ulcers.

Moynihan, in his classical contribution to this subject, refers to the following types of ulcer:

(1) Ulceration of duodenum in burns and scalds; (2) uremic ulcer; (3) tuberculous ulceration; (4) ulcer in the newborn; (5) chronic duodenal ulcer.

He states, however, that his remarks regarding symptomatology, diagnosis, and treatment refer to chronic indurated ulcers. Following his precedent, our statements, unless otherwise stated, will refer to chronic ulcers with induration or cicatricial scars.

The Roentgen diagnosis of postpyloric ulcer is made on morphologic changes in the cap, as observed in serial plates. These changes are due (1) to the crater; (2) to induration or cicatricial connective tissue surrounding the crater.

Moynihan says the crater is usually the size of the end of a lead pencil. This may be surrounded by a cicatricial scar the size of a sixpence, or an indurated mass the size of a hen's egg. It is obvious that the smallest of these ulcers, as described by him, could not occur in the cap without constantly deforming it.

The cap may be deformed by the ulcer in the following ways:

(1) Clover-leaf deformity, most common form—Fig. 584; (2) half of the cap may be involved—Fig. 585; (3) whip-lash deformity, encir-

FIG. 578.—GASTRIC ULCER—PENETRATING.
FIG. 579.—GASTRIC ULCER—BURROWING.
FIG. 580.—GASTRIC ULCER—SUBMUCOSAL.
FIG. 581.—GASTRIC ULCER—MUCOSAL.
FIG. 582.—GASTRIC ULCER—HOUR-GLASS—NICHE.
FIG. 583.—GASTRIC ULCER—FLORID.

cling and constricting the cap—Fig. 586; (4) thickening of the sphincter on one side of the lumen and not on the other side, similar to fistula in ano—Fig. 587; (5) the ulcer may be tucked away behind the cap near the descending duodenum. Moynihan says these are difficult to detect surgically. Cole failed to recognize the one shown in Fig. 588; (6) the uninvolved portion of the cap may dilate and take on the reservoir

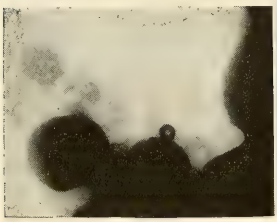


Fig. 584.

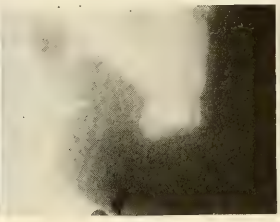


Fig. 585.

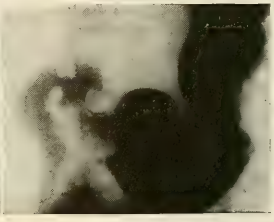


Fig. 586.

Fig. 587.

Fig. 588.

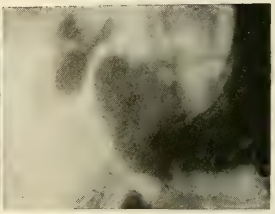


Fig. 589.

Fig. 590.

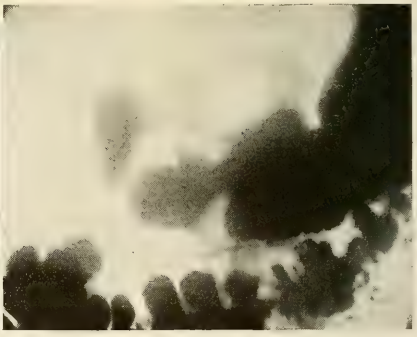


Fig. 591.

Fig. 584.—Postpyloric Ulcer—Clover Leaf Deformity.
Fig. 585.—Postpyloric Ulcer—Half of Cap Obliterated.
Fig. 586.—Postpyloric Ulcer—Whip-lash Deformity.
Fig. 587.—Postpyloric Ulcer—With Deforming Band or Crease.
Fig. 588.—Postpyloric Ulcer—Ulcer Tucked Behind Cap.
Fig. 589.—Postpyloric Ulcer—Dilatation of Uninvolved Portion of Cap.
Fig. 590.—Postpyloric Ulcer—Cap Distorted Beyond Recognition.
Fig. 591.—Postpyloric Ulcer—Sphincter Involved.

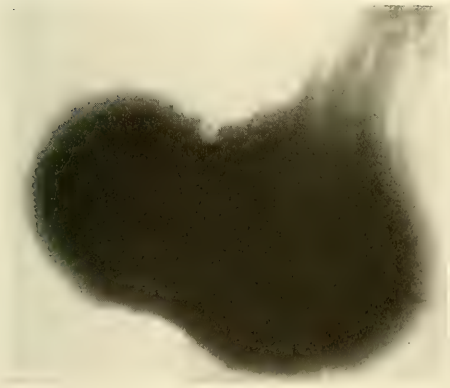
function of the cap—Fig. 589; (7) the cap may be destroyed beyond recognition by induration or cicatricial contraction—Fig. 590; (8) the induration may extend beyond the sphincter and involve the stomach—Fig. 591; (9) with any of the above deformities a crater may be shown.

Roentgenologically, postpyloric ulcers are readily divided into two groups: *first*, those with pyloric stenosis and failing or failure of com-

pensatory gastric peristalsis; *second*, those having simple deformities of the cap due to induration or cicatrix, without stenosis, and with a normal or extra rapid gastric evacuation.

The first group usually has symptoms so characteristic that Moynihan says the diagnosis could be readily made by correspondence. In the second group frequently the symptoms are so obscure that they do not lead the clinician to suspect ulcer, and a preoperative diagnosis can only be established by a Roentgen examination.

Moynihan says the treatment of chronic duodenal ulcer without exception is surgical. This observation is true of the first group, where the symptoms are so severe and so characteristic; in this group the diagnosis can be confirmed by fluoroscopy or a single plate examination (Fig. 592). The statement, however, does not apply to Group 2, where the symptoms are not characteristic and not severe, and where the diagnosis can only be established by serial roentgenography (Fig. 593).



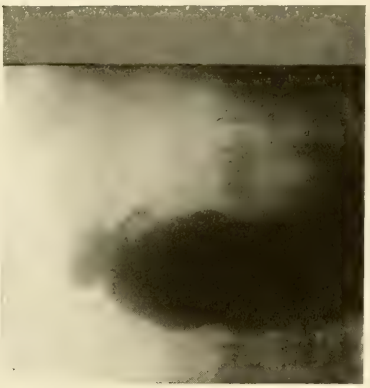


Fig. 592. Fig. 593.

Fig. 592.—Surgical Intervention Indicated.
Fig. 593.—Surgical Intervention Not Indicated.

There are cases in Group 2 where the lesion is relatively small, but the symptoms are so severe and persistent as to demand surgical procedure. But in a study of 100 cases (part of which were treated surgically and part medically) there were as many of these cases in Group 2 in which the symptoms were relieved under medical treatment as there were by surgical interference. It must be definitely understood that this applies only to the second group. In the 100 cases, 37 per cent. of cases fell in Group 1, with Roentgen findings which demanded surgical relief; 63 per cent. in Group 2, in which surgical treatment was demanded only on account of severity of the symptoms or repeated relapse.

Gall-bladder Pathology.—Pathologic changes in the gall-bladder are due to infection. Roentgenologically, these changes manifest themselves in three ways: (1) by the size and density of the gall-bladder; (2) by adhesions to the stomach, cap, descending duodenum, and hepatic flexure of the colon; (3) by calculi—usually a late change. Moynihan picturesquely refers to the latter as the "tomb-stones of a dead infec-

tion." The Roentgen information for the above findings is obtained by two distinctly different types of *x*-ray examination. The findings under headings (1) and (3) are obtained by a direct examination of the gall-bladder region, without an opaque meal; the findings for the second heading must be detected by a complete serial examination of the barium-filled gastro-intestinal tract.

Dilated or hypertrophied gall-bladders, particularly those containing thick, tarry bile, are very frequently detected in a satisfactory roentgenogram. George considers that any gall-bladder the outline of which can be definitely shown is a pathologic gall-bladder. Exception has been taken to this statement, and other observers contend that a normal gall-bladder can, at times, be shown.

Gall-stones are detectable either by their increased or diminished density relative to the surrounding bile. The density of the particular gall-stone depends on the relative content of cholesterin or calcium salts. Experimental work done on this subject showed that approximately 20 per cent. of a number of gall-stones examined contained sufficient calcium salts to render positive shadows in *x*-ray plates, and that about 60 per cent. were sufficiently less dense than the surrounding bile to cast negative shadows in *x*-ray plates. The remaining 20 per cent. approximated the density of the surrounding bile so closely that shadows were difficult to detect.

George has shown that by exercising great care, both in the making and interpretation of the plates, that gall-stones may be detected much oftener than is the case when a more or less casual examination is made. While the percentage of positive findings is sufficiently high to justify the routine examination of clinically suspected gall-bladders, it must be borne in mind that, owing to the chemical composition of stones, a negative *x*-ray finding does not warrant a negative clinical diagnosis.

The group of gall-bladder infections which is associated with a localized peritonitis, resulting in adhesions to the adjacent hollow viscera, is clinically more important than the group in which gall-stones, without adhesions, are present. The *x*-ray diagnosis in this group of cases is based on deformity, displacement, and lack of mobility in the adjacent hollow viscera. This information is necessarily elicited by an examination of the barium-filled gastro-intestinal tract, preferably by a fluoroscopic and complete serial examination of the stomach, intestine, and the enema-filled colon. The characteristic findings of these gall-bladder adhesions will be enumerated in the following section.

Pyloric and Postpyloric Adhesions.—Adhesions in the right hypochondrium involving the pyloric end of the stomach and cap, descending duodenum, hepatic flexure, and colon cause definite roentgenologic findings. The gall-bladder is the most common etiologic factor, but there are other causes, such as developmental membranes (Harris) and a further group of cases, where the etiologic factor is unknown. Such cases were described by Morris as "cob-webs in the attic." All of these pathologic conditions give definite roentgenologic findings, and in many instances the manner in which these adhesions involve the adjacent

Lesions.	Cancer.	Gastric Ulcer.	Spasm.	Hour-glass; Non-malignant.	Gall-bladder Adhesions.	Postpyloric Ulcer.	Diverticula.
Cardinal characteristics.	The lumen of the involved area is encroached upon by a nodular or smooth mass which is constant in size, shape, and position, and free from rugæ, peristaltic sulci, and craters.	The contour of the gastric wall shows a deformity projecting beyond the gastric outline—not encroaching on the lumen—the deformity being caused by the destruction of the mucosa, submucosa, or muscularis, and represents the crater or niche of the ulcer.	The rugæ show more distinctly than normal, and run obliquely or transversely, and the peristaltic sulci are broad and shallow.	A characteristic bilocular stomach with the lumen at the area of constriction markedly encroached upon, and with or without evidence of a crater.	Displacement of the stomach to the right with the pars-pylorica adherent to the liver or gall-bladder, cap displaced to the left and angulation of the descending duodenum.	A persistent deformity of the cap, frequently resembling a clover leaf; with or without a crater, or a pyloric stenosis, or a simple mucosal crater without a contracting deformity.	A pouch variable in size protruding beyond the lumen of the stomach, cap, or duodenum; free from rugæ or peristalsis.
Portion involved in order of frequency.	1. Stomach, pars-pylorica, lesser curvature, cardia, in order of frequency. 2. Duodenum and cap rarely.	Anterior and posterior wall near lesser curvature.	Pars-pylorica, sphincter, and cap—spasm diffuse; cardia spasm localized.	Pars-media; pars-pylorica; pars-cardia.	Pars-pylorica (greater curvature), cap (lesser curvature), duodenum (descending), hepatic flexure.	Cap, anterior surface, left side and posterior surface.	Duodenum; descending portion near ampulla; horizontal portion, rarely cap.
Lumen of the involved area.	Is diminished and shows a deformity that is constant in size and shape (excepting the involved portion of the segment).	Is increased by the depth of the crater and is decreased by the induration surrounding the ulcer and by cicatricial contraction.	Is evenly diminished in diameter according to the degree of spasm, but does not dilate to its normal size.	Is diminished according to the degree of cicatricial contraction. The constriction is constant in size and shape.	Is not diminished in the gastric lesion, may be diminished in the cap and is diminished in the descending duodenum.	Is diminished by the induration and cicatricial contraction except in the simple mucosal craters, where it is increased.	Is not altered unless by pressure from without by the pouch.
The extent of involvement relative to the length of the viscus involved.	Is relatively large compared to the depth to which it involves the lumen.	Is usually relatively small, but the combined crater and induration may involve the entire lesser curvature.	May be great, simulating an extensive cancer, or localized, simulating an hour-glass or peristaltic contraction.	Is relatively small. It is a ring-like narrow constriction resembling a deep peristaltic wave, but does not progress pylorusward.	May be small, forming a crease or fold, or may be extensive, involving the pars-pylorica, cap, and duodenum.	Is usually large, but may be a small indentation or crater.	Is extremely variable.
Rugæ in involved area.	Absent.	Absent.	Present; accentuated run obliquely or transversely.	Present in both pouches; absent in the constriction.	Present, but may be distorted.	Absent.	Absent.
Peristaltic sulci in involved area.	Absent.	Absent. An incisura resembling a peristaltic wave may occur on the opposite curvature from the crater.	Are distorted and shallow.	Are absent. They progress to the constricting ring and continue beyond the constriction.	Are shallow and interrupted.	Absent, but there may be increased gastric peristalsis where stenosis exists.	Absent.
Line of demarcation of invasion.	Is characterized by nodular indentations similar to finger prints, or it may be a clear-cut, well-defined line.	Is nodular. The everted edges of an indurated ulcer may resemble a single nodule on each edge of the crater.	Is characterized by a serrated appearance due to the rugæ coming to the surface. This serration is much finer than the "finger print" deformities of cancer.	Is clear cut and well defined, sometimes having a puckered appearance where the rugæ are drawn together as if by a string encircling the stomach.	Is not well marked. The adhesions gradually shading off into the normal stomach.	*i. e.*, that is, the outline of the circumscribed indurated mass or the edge of the cicatricial contraction are clear cut and constant throughout.	If the neck or opening of the pouch might be called such, has a puckered appearance.
Displacement of the viscus.	Is not characteristic except in extensive growths of the lesser curvature, when the pars-pylorica may be drawn up toward the cardia.	Is not present except where perforation and adhesions bind it to adjacent viscera.	Absent.	Is usually absent; adhesions may bind it to adjacent viscera.	The stomach to the right and angulation of the cap to the left is the characteristic finding.	Is singularly absent. This is the chief differentiating characteristic between ulcer and gall-bladder adhesions.	Is absent except where the pouch is very large, in which case it may distort the course of the descending duodenum.

viscera helps one in determining whether the gall-bladder is the offending organ, or whether the lesions arise from obscure causes.

Adhesions of gall-bladder origin usually involve the extreme pyloric end of the greater curvature of the stomach (Winslow), causing it to be drawn to the right and adherent to the under surface of the liver, or to the gall-bladder, with displacement and angulation of the cap to the left, relative to the pyloric end of the stomach. This displacement of the stomach is readily shown with the patient in the prone posture (Fig. 594), but when the patient does assume the erect position, this region will appear to be more or less firmly fixed to the under surface of the liver, and the extreme pyloric end of the stomach has the appearance of the roof of a tent against the under surface of which a stick has been thrust (Fig. 595).

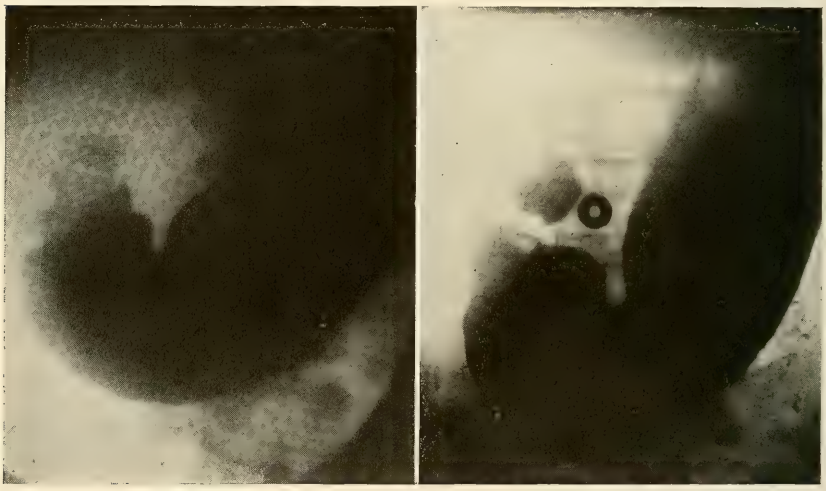


Fig. 594. Fig. 595.

Fig. 594.—Pyloric Adhesion—Pyloric Displacement.
Fig. 595.—Pyloric Adhesions—Pyloric Tenting.

These are the mildest types of non-obstructive lesions; the more extensive ones cause marked deformities of both the pyloric end of the stomach and the cap. If the gall-bladder adhesions are more marked around the cystic or the common duct, the roentgenologic findings are more likely to be angulation of the upper part of the descending duodenum, with obliteration of the characteristic ring-like folds of the valvulæ conniventes. The rather broad membrane crossing the cap, involving the cap and pylorus, described by Harris, is occasionally observed, and, in addition to this, there is sometimes a more or less generalized type of slight adhesion involving the stomach and cap. The etiology of this condition is undetermined even after surgical exploration. In about 10 to 15 per cent. of the cases in which there are definite roentgenologic findings of a pathologic process, involving the stomach and cap and descending duodenum, one is unable to make a differential diagnosis between postpyloric ulcer and adhesions of gall-

bladder origin. In this group of cases one must make a diagnosis of the organic lesion and state that the weight of roentgenologic evidence is in favor of one or the other, without making a statement as to the etiologic factor producing the lesion. In about half of the obscure cases which come to operation there is noted both ulcer and gall-bladder adhesions.

Lesions of the Descending and the Horizontal Duodenum.—*Diverticula.*—The very great frequency with which this condition occurs has not been recognized in America. Linsmayer states that duodenal

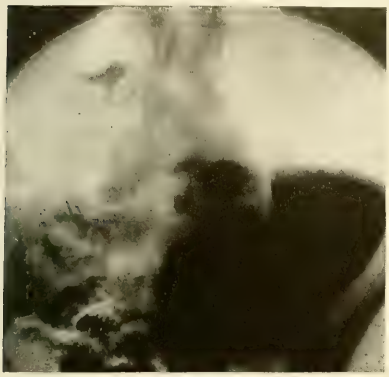


Fig. 596.

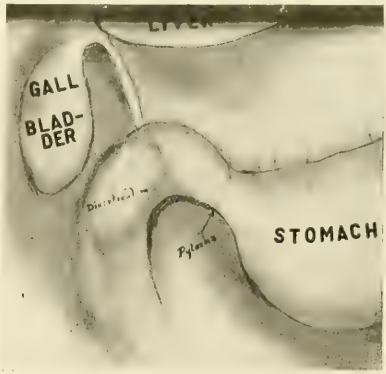


Fig. 597.

Fig. 598.

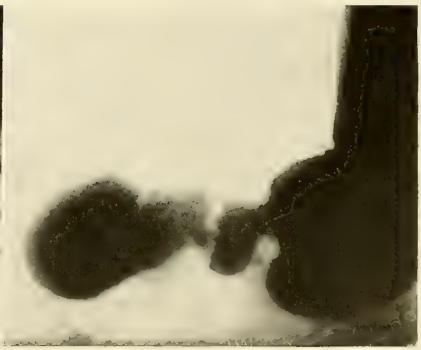


Fig. 599.

Fig. 596.—Duodenal Diverticulum.
Fig. 597.—Operative Finding of Case Fig. 596.
Fig. 598.—Mesenteric Ileus.
Fig. 599.—Megaloduodenum.

diverticula have been found in 2 per cent. of gross autopsies in which a detailed examination of the duodenum has been made. Based on our experience, since we have learned to recognize the findings characteristic of this lesion we believe that this estimate of 2 per cent. is relatively small.

The *x*-ray finding characteristic of this lesion (Fig. 596) consists of a barium-filled pouch protruding beyond the lumen of the duodenum, stomach, or cap, connected with the duodenum by a small neck, which may or may not be shown.

These diverticula vary in size from that of a pea to that of a hen's egg. They are most frequently found sprouting from the descending duodenum, and in a large proportion of cases these occur around the ampulla of Vater, for which reason the French have referred to them as diverticula duodeni perivaterens.

They are of interest, first, because of their frequency, which has not hitherto been recognized; second, because at least some of them are associated with symptoms; and third, because of the great importance of differentiating them from, and not mistaking them for, other conditions of extreme clinical and surgical significance.

Mesenteric Ileus.—This consists of a partial obstruction of the horizontal duodenum due to pressure by the root of the mesentery, with dilatation of the descending and proximal portion of the horizontal duodenum. This condition has been described by Codman, who has wax casts showing its occurrence (Fig. 598).

Organic Lesions of the Small Intestine.—These are not often diagnosed by means of the Roentgen ray. There are a few cases reported of obstruction due to carcinoma (George) or other causes in which it has been possible to demonstrate the barium and the great dilatation of the intestine down to the region of the constriction. In cases of acute intestinal obstruction, where there is a marked accumulation of gas and a constriction of the gut, the coils of the small intestine are readily visible. Occasionally one can determine the point of obstruction.

Lesions of the Terminal Ileum.—These have attracted a great amount of attention, due largely to the work of Lane and Jordan in their discussion of ileal stasis. It is our belief that these lesions do occur and that the angulation and fixed portions of the terminal ileum, with or without accompanying adhesions involving the left side of the cecum, can be detected by either roentgenologic or fluoroscopic examination of this region; but we do not believe that these lesions occur with anything like the frequency that has been asserted by some observers.

Megaloduodenum.—Congenital malformations that occur in the duodenum are readily detectable by the *x*-ray. True congenital deformities in this region must be differentiated from dilatations due to obstruction, diverticula, and deformities of the stomach. Such a complicating differential diagnosis is illustrated in Fig. 599, where owing to the shape, position, longitudinal rugæ, and constriction characteristic of a sphincter indicated a tremendously enlarged cap, but fluoroscopic observation showed each progressive peristaltic wave progressed to and became established beyond the constricted area. This constricted area, therefore, was misinterpreted as the constriction of an hour-glass stomach.

Lesions of the Appendix.—The value of the *x*-ray findings as evidence of a diseased appendix is a mooted point. There are no such characteristic findings for these lesions as exist for the organic lesions of the stomach and cap, but there are lesser signs which are indirect evidence of a diseased appendix. This method of examination is not in its present stage of development applicable in the diagnosis of acute

and probably not the subacute appendical lesions. The Roentgen findings are dependent upon chronic changes in the appendix, resulting in irregularities and kinks in its lumen, and causing failure of evacuation, and adhesions involving the adjacent hollow viscera, particularly the caput coli between the appendix and ileocecal valve (Fig. 600). There is much discussion as to whether the kinked, angulated, segmented, and retentive appendix is sufficient evidence on which to base a diagnosis. Experience has taught that many individuals with such Roentgen findings live for many years without symptoms referable to this region. In many instances, however, a clinical history of at least a single previous attack can usually be elicited. If, in addition to the previously described findings, the appendix fluoroscopically visualized is associated with a localized pressure tender point referable to the appendix, the clinical significance of these findings is greatly accentuated. Another finding elicited is the pain referred specifically to the appendix when directed by the fluoroscope, pressure is exerted over the descending colon, with the entire colon filled with a barium clysma. These findings should never be used solely as a basis for the diagnosis or indication for surgical procedure, but if such *x*-ray findings are accompanied by a characteristic clinical history, the findings may be used as strong corroborative evidence.

Incompetent Ileocecal Valve.—An enema or barium clysma without any unusual pressure will at times pass through the ileocecal valve. That this condition can be diagnosed by roentgenography is an established fact (Fig. 601). These cases we classify into three degrees, depending upon the quantity of regurgitation, the distance that it passes up into the small intestine, the amount of deformity of the cecum at the valve, and the character of the dilatation of the terminal ileum. The clinical significance of these regurgitations has been the subject of much controversy. We are unable to appreciate the point of view that a third degree of incompetency of the valve can be of no clinical significance especially when there is a deformity of the cecum and a dilated terminal ileum, which almost invariably shows a stasis by the barium meal, and where the colonic contents habitually regurgitate all the way back to the duodenum.

Colonic Lesions.—The progress of the barium meal through the colon may be determined by periodic plates which are usually made at six, twenty-four, and forty-eight hours following the administration of a meal. Stasis, colonic motility, appendical retention, and colonic diverticula are best detected by these plates. Partial obstruction by adhesive bands or intrinsic or extrinsic growths may be detected by periodic plates.

Our chief reliance for the *x*-ray diagnosis of organic lesions of the colon must be placed on that evidence obtained by the stereoscopic plates of the colon after the injection of a barium clysma. Preferably, the stereoscopic plates should be supplemented by a third plate made three to five minutes later to eliminate the possibility of filling defects being due to spasm. In a previously evacuated colon 3 pints of the

barium clysma will fill the colon to the cecum, giving the contour of practically the entire colon. If the clysma does not pass all the way to the cecum it is evidence of an obstruction *in* the gut, *on* the gut, or *of*

FIG. 600.

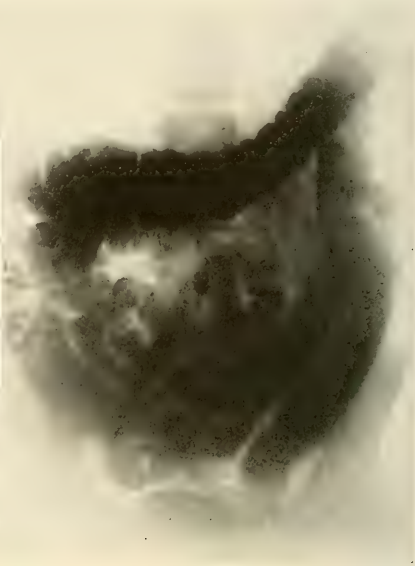


FIG. 601.

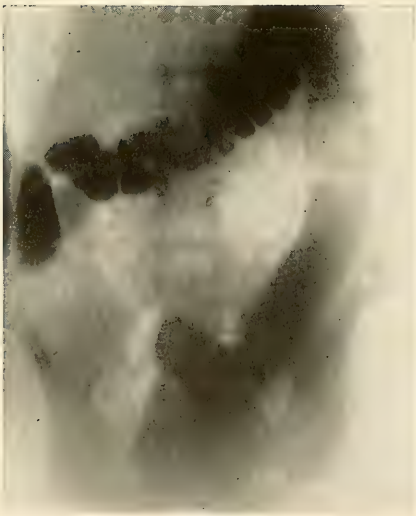


FIG. 602.

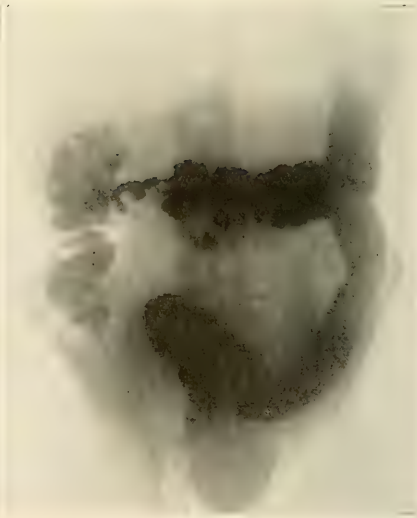


FIG. 603.

FIG. 600.—CHRONIC APPENDICITIS.
FIG. 601.—ILEOCECAL INCOMPETENCY.
FIG. 602.—CARCINOMA (COLON).
FIG. 603.—COLONIC ADHESIONS—NON-OBSTRUCTIVE.

the gut. This statement includes obstructions *in* the gut which may be due to incomplete evacuation of the colon even after an attempt has been made to have it evacuated by vigorous catharsis.

Carcinoma of the colon as low as the brim of the pelvis is readily seen in a pair of stereoscopic plates of the colon previously filled with the clysma (Fig. 602). There are some cases in which the location and extent of an organic lesion can be readily recognized by the Roentgen method where it may be difficult to establish a differential diagnosis between malignant and non-malignant obstruction.

Carcinoma involving the sigmoid or the pelvic colon below the brim of the pelvis, but which has not yet become obstructive, is more difficult to diagnose by the roentgenologic method than in any other portion of the colon. This is because the coils of the uninvolved portion of the colon fill the pelvis in such a way as to obscure the small area of non-obstructive carcinoma. When a lesion in this region is suspected, and an enema is administered under fluoroscopic control, the manner in which the solution is observed to pass the lesion gives additional data as to its location.

Adhesions Involving the Colon.—These are definitely divided into two groups—non-obstructive and obstructive. The former non-obstructive adhesions usually involve the ascending colon, cecum, and hepatic flexure, and are usually caused by appendical lesions or gall-bladder infections (Fig. 603). The adhesions are of more significance as a diagnostic sign for the gall-bladder or appendical lesion than of importance in themselves. Obstructive adhesions are usually characterized by a sharply defined circular constriction when caused by definite bands, which delays the progress of the bismuth impregnated meal, and obstructs or partially obstructs the flow of the barium enema toward the cecum (Fig. 604).

Veils and Membranes.—These have been described under the terms "Jackson's membrane," "pericolonic veils," or "developmental membranes." They involve the ascending colon, causing a definite line of torsion upward and outward, with the rotation of the anterior longitudinal line of the colon to the right. They frequently involve a loop of the descending portion of the transverse colon. They are readily recognized in stereoscopic Roentgen plates after administration of the barium clysma.

Dilated and Mobile Cecum.—Extreme dilatation of the diameter of the colon associated with mobile cecum, which drops down into the pelvis, is a condition readily recognized by the barium clysma. Whether this displacement is the cause of constitutional symptoms and demands surgical relief is debatable.

Lawrason Brown and Sampson have recently done some work on tuberculous colitis. The work is admirably summed up in the following conclusions:

1. Tuberculous colitis can be diagnosed clinically with a considerable degree of certainty when the disease is far advanced.

2. On the other hand, in the early or latent stages, when remedial measures may prove of avail, the clinical picture may be of little aid in diagnosis.

3. In all stages certain shadows cast by the barium meal at the end

of six, eighteen, and twenty-four hours determine definitely the presence of colonic ulcerations, but the absence of such shadows does not absolutely exclude colonic ulcerations.

4. The roentgenologic picture shows hypermotility and spasm or filling defect.

5. The presence of such a picture in a patient with pulmonary tuberculosis should lead to a definite diagnosis of colonic tuberculosis.

6. Tuberculous colitis occurs far more frequently than hitherto supposed. It must be excluded in all advanced cases and in any early cases with any abdominal symptoms, before submitting the case to radical treatment.

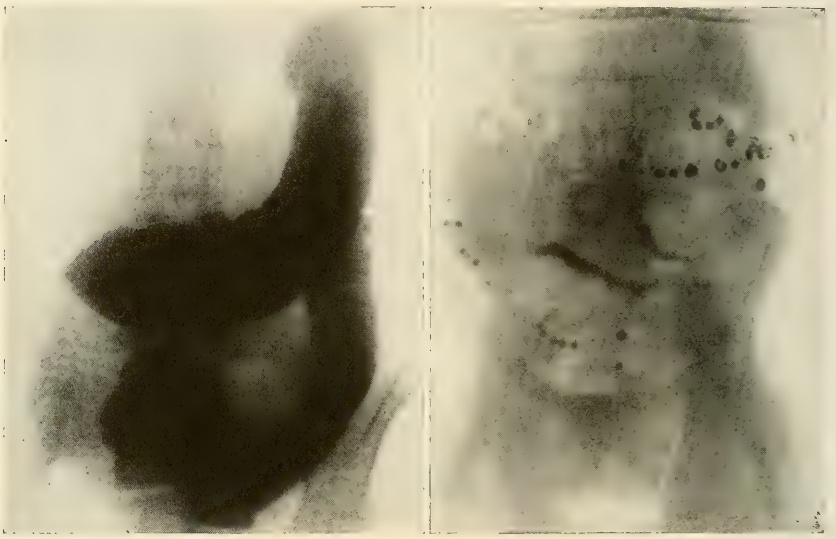


Fig. 604. Fig. 605.

Fig. 604.—Colonic Adhesions—Obstructive.
Fig. 605.—Colonic Diverticula.

7. No examination of a patient with pulmonary tuberculosis today can be considered complete without a roentgenologic study of the intestine.

Diverticula.—These occur in any portion of the colon, but with the greatest frequency in the descending colon near the sigmoid (Fig. 605). These are readily detected by their retention of the barium-impregnated meal or enema. However, they are usually not filled immediately after the injection of the enema, as time is required for the barium to permeate the fecal-filled pouches. Nevertheless the serrated appearance of the barium-filled gut is a roentgenologic sign of their existence, and should indicate the necessity for subsequent plates to show the outline of the pouches.

Roentgen Examination of the Abdominal Organs Following Oxygen Inflation of the Peritoneal Cavity.—Stein and Stewart have described the

following method which appears to open up a new field in abdominal diagnosis (Figs. 606, 607):

"The simple method employed by us is as follows: After the patient is prepared in the usual manner for Roentgen examination (thorough cleaning out of the bowels and emptying of the bladder) he is put flat upon his back and the abdomen is then inflated with about 3 to 4

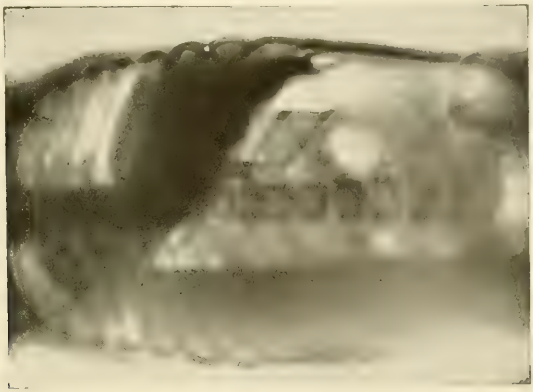


Fig. 606.

Fig. 607.

Fig. 606.—Oxygen Injected Abdomen. (Stein and Stewart.)
Fig. 607.—Oxygen Injected Abdomen. (Stein and Stewart.)

liters of oxygen. The whole outfit required for this procedure consists of an oxygen tank to which is attached a rubber bag (such as is used with the gas-oxygen apparatus for anesthesia) with a capacity of about 1 gallon or 4 liters. To this bag is attached a small rubber tube which can be easily connected with a regular lumbar puncture needle. The spot where the needle is to be inserted is sterilized with iodin and the skin rendered insensitive by an injection of novocain-adrenalin solu-

tion. The spot from which in our judgment it is easiest to inflate the abdomen is 1 to 2 inches to the left of the umbilicus and about $1\frac{1}{2}$ inches below it. The procedure is very simple. Anyone who has had surgical experience can easily gage the thickness of the abdominal wall. Our practice is to push the needle to a point where it pushes through fascia, muscle, and peritoneum without any difficulty. The plug is then removed from the needle and the needle is connected with the rubber tube. A slight pressure for four or five minutes and the amount of oxygen to be introduced varies between 3 and 4 liters or nearly 1 gallon. When the abdomen is entirely distended the patient usually complains of a sensation of fulness and slight pains in the shoulders (the latter apparently due to pressure against the diaphragm). As far as the fate of the oxygen is concerned, it is usually absorbed without any trouble within twenty-four hours."

A few words must be said about the apparent danger of puncturing the intestines. Experience has shown us that the elasticity of the intestines permits them to recede before a sharp intruding body, such as a needle, provided that caution is used and the needle advanced slowly. We ourselves have encountered no difficulties in this respect and have experienced no untoward effects.

In the horizontal position, with the patient's back to the table, we were able to demonstrate some very marked postoperative adhesions between the intestines and the parietal peritoneum. We also demonstrated with great clearness a large carcinoma of the ascending colon.

Pathologic conditions, such as carcinomatosis, cirrhosis or marked hypertrophy of the liver, enlargement of the spleen and tumors of the stomach and intestines, as well as those of the genital organs, are now easily demonstrated. The procedure which we are presenting on the basis of its obvious merits promises a wide extension of the diagnostic scope of the Roentgen rays in the domain of gynecologic and general abdominal surgery.

Fractures.—The earliest use of *x*-rays was in the diagnosis of fractures. The use of *x*-rays has advanced to such a point that today one is justified in even searching for fissure fractures at the base of the brain. The use of the rays as a guide to the treatment of fractures has been so developed that no one is now justified in clinically treating detectable fractures without first determining the character of the fracture by an *x*-ray examination (Figs. 608, 609) if this is possible.

In injuries near the joint, even where, clinically, no fracture is suspected, the plates very often show small fractures which are of definite clinical significance.

There are instances in which the manipulation necessary for a thorough physical examination has resulted in establishing an altered relation in a fracture that did not previously exist. This necessitated an effort at reduction which could have been avoided had the character of the fracture been known prior to the manipulation.

The accuracy of the *x*-ray diagnosis of fractures depends on the character of the plates made and the care and experience used in their

interpretation. The greatest source of error exists where the examination consists in a careless observation of a single flat plate, especially if the part has been examined in only one direction. A careful study of stereoscopic plates made in at least two directions and compared with similar plates of the opposite, corresponding, normal part, constitutes an ideal examination and will reduce the source of error to a minimum.

FIG. 608.

FIG. 609.

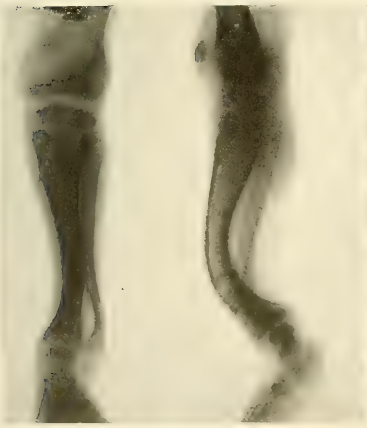


FIG. 610.

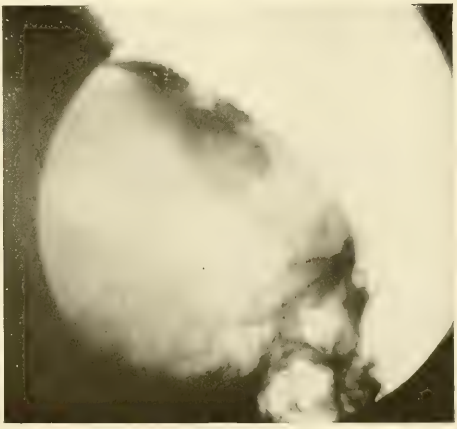


FIG. 611.

FIG. 608.—FRACTURE.
FIG. 609.—FRACTURE.
FIG. 610.—LATE RICKETS.
FIG. 611.—SYPHILIS OF FRONTAL BONE.

Exact anatomic restoration is an ideal to be desired in treating fractures, but this is not usually obtainable and is not essential to a good functional end-result. It must be borne in mind when studying *x*-ray plates that often considerable deformity shown in the plates is compatible with a good end-result, both cosmetic and functional.

In studying *x*-ray fracture findings the following points should be observed: (1) Lines of cleavage; (2) alinement; (3) bearing surface;

(4) the presence of altered relation in joint surfaces; (5) bony protrusions that might limit joint movements.

Methods of graphic study by a system of lines, the purpose of which is to show the angulation of joint surfaces in relation to the axis of long bones as a means for the ideal functional restoration of a joint, have been devised by George, Skinner, Cole, and others.

The adjustment of fractures under *x*-ray control is an ideal method. The flexible equipment, such as the bedside units already described, renders this method easy of application and practical. By the use of such bedside equipment the study of the progress, repair, and maintained position can be studied with remarkable ease.

Realizing that bone atrophies following injury and non-use Blake observed that detached spiculæ or fracture surfaces without nutrition did not atrophy (ebonization), but showed a decreased radiability that was readily detectable in *x*-ray plates.

That infection did occur in joints removed from infected compound fractures was known, but the route of infection was uncertain until Leriche accounted for these infections by extension through the channel of minute fissure fractures with lines of cleavage running into the joint surface. A similar observation shows that infection in the maxillæ is often disseminated through the channel of a fissure fracture which runs into the peridental structure of an infected tooth.

Chutro uses serial *x*-ray examinations for determining the end-point of bone atrophy as a guide to the proper time for the use of bone-grafts.

Structural Lesions of the Bones and Joints.—Pathologic lesions in the bones and joints result in more or less characteristic changes in the contour and structure of the bones (Figs. 610, 611). Structural changes in the cortex, medulla and periosteum, epiphyses, and joint surfaces, whether productive or destructive, may be detected with a remarkable degree of accuracy and the progressive or retrogressive changes observed by periodic examinations. In some instances these changes are so characteristic that one may make a definite diagnosis of the etiologic factor, while in other cases it is impossible. This applies especially to the productive periosteal lesions which may be due to a varying etiology.

Acute osteomyelitis in its early stages shows no alteration in the contour or structure of the bones, and as a consequence the negative *x*-ray findings do not preclude the possibility of the presence of such an infection and should not weigh against a clinical diagnosis of such a lesion. A localized area of increased density without well-defined edges, cloudy in appearance, due to congestion and exudation, is one of the earliest *x*-ray findings of acute osteomyelitis, and can only be detected when the affected part is compared under the same *x*-ray conditions with the opposite corresponding normal part.

Skepticism exists concerning the diagnosis of displaced or detached semilunar cartilages in the knee-joint by the *x*-ray method. It has been the consensus of opinion that the normal attached semilunar

cartilage is not shown in *x*-ray plates. George has recently contended that the external edge of the normal cartilage is shown in satisfactory plates, and that we have previously failed to recognize and properly interpret this finding. If this statement, which appears to be true, is accepted it forms a very definite basis for either the negative or positive diagnosis of such lesions. Diminished interarticular spacing on the affected side, especially when associated with slight localized irregularities in the bone along the attached margins of the cartilage, are *x*-ray findings of diagnostic significance. It is a well-recognized fact that detached cartilages undergo chronic pathologic changes which render them of such density that they are readily detectable.

Head.—The cranial bones are susceptible to the same changes and lesions as other bones, and these changes must be differentiated from the changes in the skull due to increased intracranial pressure, from such lesions as tumors and hydrocephalus. Tumors of the brain have been shown in 6 per cent. of a series of 100 cases in Halsted's Clinic (Baltimore) by their increased densities as shown in *x*-ray plates. Tumors of the hypophysis are diagnosed in the majority of instances by the manner in which they deform and produce destruction of the sella turcica and the clinoid processes.

Previously the *x*-ray diagnosis of hydrocephalus had been based on changes in the inner table of the skull produced by convolutional pressure and the undue separation of the sutures. The recent work of Dandy has opened in ventriculography an immense field for the diagnosis of lesions of the brain. (See Neuhof's chapter on the Head.)

The Accessory Sinuses.—These sinuses are normally filled with air, therefore their size, shape, and the septa between them are sharply defined. When infected they contain an exudate of greater density than the air which is displaced, and the contrast between the normal and the infected sinus is evident. Destruction of the walls of the mastoid and ethmoid cells may be detected, and the sclerosis that occurs as a late manifestation of the process is readily detected and differentiated from the early stage of the infection. Infections of the ethmoid cells are sometimes difficult to recognize. The detection is facilitated very often by making oblique plates when the posterior cells will be shown through the opposite orbit. The size and shape of the sphenoidal sinuses may be determined in lateral plates, but the presence of infection is best shown in plates made in the vertical direction.

A System of Jaw Positions.—The oral surgeon desires to have uniformity in the series of radiographs that are essential to the diagnosis and to detecting the progress of injuries and disease in the maxillæ. It is almost essential to the intelligent study of the repair of these lesions that the series of plates made should show anatomic relations that are uniform. By methods previously employed this was more or less impossible. The following method devised by Ciezynski and described by Misch appears to accomplish the desired result. It was used by roentgenologists working with the faciomaxillary surgeons of the A. E. F. in France to the apparently entire satisfaction of the

surgeons. For the technic of the method one is referred to the article of Misch. In Fig. 612 the essentials of the method are illustrated.

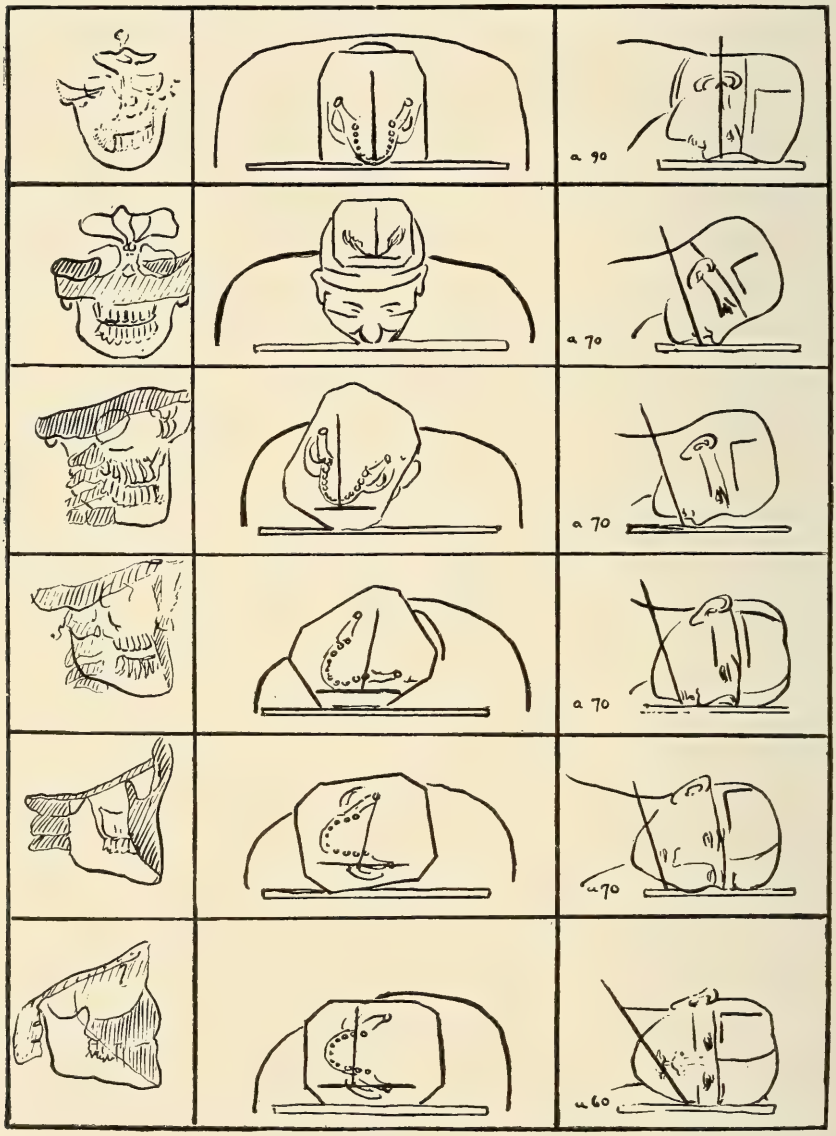


Fig. 612.—System of Jaw Positions.

In Column 1 is shown the regions that one desires covered in the examination.

In Column 2 is shown a frontal position of the head with a cardboard diagram showing a projection of the inferior maxilla and the

incidence of the normal ray that is necessary to obtain the anatomic result pictured in Column 1.

In Column 3 is shown a side view of the necessary head position with the lines indicating the incidence of the normal ray to obtain the

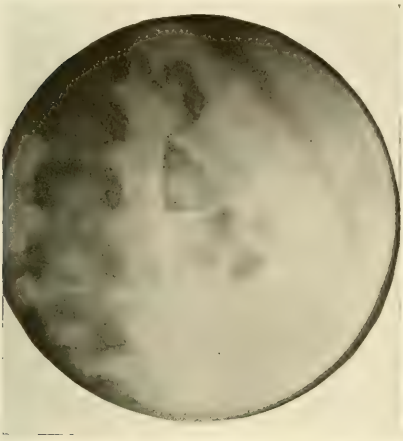


Fig. 613.

Fig. 614.

Fig. 615.

Fig. 613.—Renal Calculi.
Fig. 614.—Ureteral Calculus.
Fig. 615.—Vesical Calculus.

result represented in Column 1. The figures in the corners of Column 3 represent the angle of incidence of the normal ray.

It is entirely feasible to use these positions for stereoscopic results.

By this method astonishingly uniform results may be obtained.

Lesions of the Urinary Tract.—The roentgenographic method of diagnosis has its chief field of usefulness in the field of urology in the detection of urinary calculi, particularly those situated in the kidney and ureter (Figs. 613–615).

There has been considerable controversy in regard to the relative accuracy of the method in such diagnoses. Opinions vary from the extreme of Hugh Cabot, who reports a series of cases where *x*-ray findings are correct in only 20 per cent. of cases examined, to that of Thurston Holland, whose percentages approximate 90.

It may be stated that the accuracy of *x*-ray detection of urinary calculi is dependent on two factors: first, quality of plates used; second, the size and chemical composition of the calculus.

Cole in 1908 enumerated the following requisites for plates having a diagnostic quality, and stated that one was not justified in making a *negative* diagnosis unless these requirements were fulfilled:

(1) *Quality of Plates.*—The plates should show the spine and transverse process all the way to the tip, the outer border of the psoas muscle; the eleventh and twelfth ribs; the outline of the kidney; the under surface of the liver. The ureteral plates should show the bony detail of the sacro-iliac synchondrosis, the bony structure of the spine and ischium, the sacrum, and coccyx, all the way to the tip. The bladder, distended with urine, is sometimes well marked.

(2) *Size and Chemical Composition of Stone.*—Urinary calculi which exhibit even minute quantities of calcium salts, and almost regardless of the size of the stone, should register a shadow in well-made *x*-ray plates. It is, however, debatable even yet whether stones of pure urate composition have a sufficient density to register shadows even on well-made plates. We believe that the size of stone as well as the density of the overlying anatomic structures are important factors in the detection of urinary concretions. Fortunately, stones of pure urate composition are not so frequent in the kidney and ureter as they are in the bladder, in which latter location they do not prove a source of diagnostic difficulty.

Another factor which has considerable influence in the diagnosis of urinary calculi is the interpretative ability of the observer reading the plates. In many cases it happens that shadows which can be diagnosed by the trained roentgenologist would be entirely misinterpreted by the inexperienced observer.

In the article above quoted were also enumerated the following points in the differential diagnosis of urinary calculi:

They should be distinguished from: (1) Fecal concretions; (2) gall-stones; (3) calcified costal cartilates; (4) osteoplaques or spiculæ of bone; (5) folds of intestine incarcerating gas; (6) enteroliths; (7) foreign bodies; (8) calcified lymphatics; (9) prostatic calculi; (10) finger marks; developer stains, flaws and defects in plates; (11) tuberculous kidney; (12) warts and moles on the back.

Roentgen Methods of Differentiation.—These include—

Stereoroentgenography.
Anteroposterior, postero-anterior, and true lateral plates.
Depth measurements, by any method referred to in this communication dealing with localization and extraction of foreign bodies.
Pyelography.
Ureteral catheterization with radiographic catheters, with either injection of fluids of increased density or inflation with gas or air.

Other Lesions of the Urinary Tract.—Other lesions in which the Roentgen method of examination is of diagnostic value are as follows:

Tuberculous kidney:	Especially those of long standing, where there are areas of calcification scattered throughout the parencychma and pelvis of the kidney.
Hydronephrosis:	By pyelography.
Nephroptosis:	(Special technic with the patient in the erect posture.)
Angulations and kinks of the ureter:	These findings must *not* be made with a single flat plate, because wide non-obstructive curves of the ureter, when viewed on edge, appear as acute angulations.
Diverticula of both ureter and bladder and of deep prostatic ureter. Neoplasms of the bladder. Enlarged prostate.	By cystography.

Special Aids to Diagnosis.—The rapid growth and development of refined cystoscopic methods, combined with injection of opaque solutions into the pelvis of the kidney, the ureter and bladder, or the inflation of the pelvis of the kidney and bladder with air or gas, form a combination of aids for use in differential diagnosis of some of the more obscure lesions previously enumerated.

Numerous materials opaque to the *x*-ray, such as collargol, argyrol, thorium, and other silver salts, have been employed, but the recent work of Cameron favored first the use of solutions of sodium bromid and subsequently that of sodium iodid. This eliminates much of the danger in the use of silver salts, and furnishes roentgenograms of more brilliant density.

The use of barium suspension in the bladder (cystography) may be used instead of more expensive suspension. Inflations of the bladder with air, especially if care be taken not to overexpose the plates, affords an excellent method of visualizing the contour of the bladder, particularly if this is done stereoscopically.

Thoracic Lesions.—The tremendous impetus given to thoracic surgery during the war has necessitated the advancement of methods of *x*-ray diagnosis in this particular field. Probably the greatest progress has been made in the fluoroscopic method. The development of flexible equipment that could be used close to the front areas of fighting and the adaptability of such equipment to bedside use has stimulated the method of fluoroscopic diagnosis of thoracic lesions and our knowledge of their progress. The immediate detection of foreign bodies and their exact anatomic localization is a feature of this method of examination. The detection of pneumothorax and hemothorax is simple. The presence of foreign bodies and their exact anatomic location, and the presence, extent, and location of air and blood in the pleural cavity give the surgeon necessary information as to the type of surgical interference.

By the fluoroscopic method it is possible to differentiate the location of foreign bodies in the substance of the lung, the heart and the diaphragms, and the parietes by their movements synchronously with

respiration, the heart impulse, and the elevation of the ribs during the respiratory act. Intrapulmonary apoplexies can be determined by the fluoroscopic method if the hemorrhage is sizable. The smaller apoplexies can be detected rather readily by the plate method. In using the fluoroscope much useful information can be obtained by a careful study of the diaphragm, its contour and elevation, and the presence, absence, or limitation of excursion will convey much useful information if properly interpreted. The early limitation of diaphragmatic movement with a partial pneumothorax where negative pressure still remains is easily observable; this limitation advances in a see-saw or pendulum movement when a complete pneumothorax and positive intrathoracic pressure is established. The limitation of diaphragmatic movement is fluoroscopically early detected in intrapulmonary consolidations, whether they are due to superimposed pneumonias of bacterial origin or the mechanical pneumonias due to intrapulmonary hemorrhage. The contralateral pneumonias which occurred in the unoperated lung so frequently with an alarming mortality are readily detectable by either the fluoroscopic or plate method; they are detectable, however, much earlier by the plate than the fluoroscopic method. The postoperative bedside study from day to day of these chest cases is no less valuable than the early diagnostic use of the method. The detection of superimposed pneumonias, pneumothorax, hemothorax, hydrothorax, pyothorax, and their progression or retrogression can be studied at the bedside with little inconvenience to the patient by either the fluoroscopic or plate method.

That the pliability of the diaphragms was gradually diminished in empyemas involving the diaphragmatic pleura has been observed fluoroscopically, and that pliability is never restored after the lesion becomes chronic had also been observed. Yates has shown recently that where there is such chronic involvement of the diaphragmatic pleura a complete muscular degeneration takes place. It has been considered previously that this absence of diaphragmatic movement was due to nervous inhibition.

Pulmonary Tuberculosis.—It is now safe to make the assertion that any tuberculous focus in lungs that can be demonstrated by careful macroscopic examination of the finest gross sections of the lung can be detected in well-made or satisfactory stereoscopic plates, and further, that by a comparative study of the various gradations of densities that are shown in such plates a fairly accurate estimate can be made of the type or stage of the pathologic change in such tuberculous lesions.

Pneumonia.—Lobar pneumonia even in its earliest clinically detectable stage is shown by *x*-ray examinations. The early stage is often characterized by a peripheral triangle of consolidation.

Bronchopneumonia.—The characteristic distribution is also shown. *Foreign body pneumonias*, the result of aspirated bodies, are distinctly shown, and often lead to the diagnosis of the presence of such foreign body if not sufficiently dense to cast a shadow.

Bronchiectasis.—This condition is recognizable in *x*-ray plates, and

the diagnosis in plates is many times made clearer if plates are made both before and after the evacuation of the pockets or cavities. Moore has classified these lesions as shown in *x*-ray plates into two types or stages: (1) the infiltrative, characterized by a marked connective-tissue hyperplasia, and (2) the cavernous, with round, spindle, or cylindric dilatations.

Pleural Lesions.—The simple serous pleurisies are readily shown in *x*-ray plates, and their progress and retrogression graphically recorded. The presence of fibrinous organization is also readily detectable.

Empyema.—The empyemas are readily classified in *x*-ray examinations according to their location into apical, axillary, diaphragmatic, mediastinal, and interlobar types. Any of these types may be either free or sacculated. As a guide to the surgeon in draining an empyema cavity it is possible to make a complete surface outline of the underlying cavity, and in the case of interlobar sacculations to measure the depth. This information is best obtained fluoroscopically. A clever method used at the Mayo Clinic for outlining empyema cavities and pockets which already have a drainage opening is to pack them with a bismuth impregnated tape, following which stereoscopic plates are made.

***x*-Ray Therapy.**—The treatment of cutaneous lesions, malignancies, and adenopathies by the *x*-ray has developed to such importance that today it constitutes a specialty in the medical field. This therapy is readily divided into two classes: (1) the superficial, which applies to lesions of the skin; (2) deep therapy, applied to any growth or adenopathy beneath the skin.

Superficial therapy may be applied in two ways: by fractional doses or by a single full erythema dose. A difference of opinion exists as to which method is most effectual and safe, but it is generally conceded that there are certain lesions which respond better to one, while others respond better to the other. The graph (Fig. 616), constructed by MacKee, forms a convenient method for estimating the dosage for the skin. This graph is based on the use of 2 milliamperes of current with a 6-inch parallel spark-gap between points and 8-inch focal point from the skin, with unfiltered rays. Only the time need be varied to obtain the desired dosage from one-eighth of an erythema dose to one full erythema dose plus. This method is more accurate than the use of pastils, which deteriorate with heat, age, and atmospheric conditions. A well-grounded knowledge of lesions of the skin and their diagnosis must be possessed by the roentgenologist or close co-operation between the roentgenologist and dermatologist must be obtained.

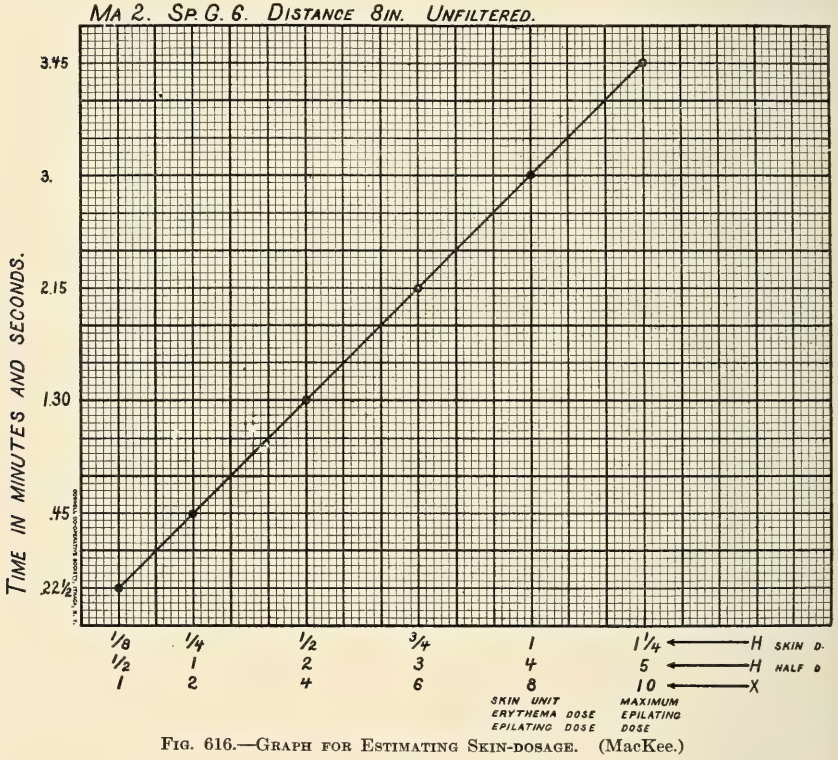
Deep therapy may be employed in one of three ways: (1) as a preoperative procedure; (2) as a postoperative procedure, and (3) as a substitute for operative procedure. It is, of course, admitted that surgical procedure is always indicated where complete excision of the growth or glandular involvement is possible. Deep therapy as a preoperative procedure is preferred by some surgeons, who believe that it not only occludes the lymphatic channels and prevents dissemination but also reduces the friability of the tumor mass, while other surgeons

oppose this preoperative therapy on the grounds that the loss of time necessary to the treatment is not justified.

Postoperative treatment has been advocated as a prophylaxis against recurrence, especially in the malignancies, and has today become a fixed routine procedure in nearly all the large clinics.

As a substitute for surgical procedure *x*-ray therapy is used in the group of cases that are considered inoperable because of either the extent of the involvement or of the anatomic location of the lesion.

Intentional removal of skin and other tissues overlying deep-seated inoperable cancers as a necessity for the effective treatment with *x*-rays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1 2 4 6 8 10 ← X
SKIN UNIT ERYTHEMA DOSE EPILATING DOSE
MAXIMUM EPILATING DOSE

FIG. 616.—GRAPH FOR ESTIMATING SKIN-DOSAGE. (MacKee.)

constitutes a new type of procedure suggested by Beck and Warner, who admirably sum up their work in the following manner: "The roentgenologist is handicapped when such cases are referred to him for treatment, for the surgeon has closed for him the door to success by suturing the wound over the area to be treated. When the surgeon realizes that the full exposure of the cancer bed is necessary to avoid recurrence he will disregard the cosmetic effect and prepare the field for efficient Roentgen treatment."

Technic.—Massive doses, using the Coolidge tube and high penetration, with thick filters of aluminum and leather, are essentials of the technic to be employed. In lesions where the focus is deep seated,

especially in those that are relatively localized, cross-firing through multiple small ports of entry is most efficacious. This is especially applicable in deep therapy in the pelvis. The recent perfection of a transformer immersed tube by Coolidge, that will deliver very high penetration and which when covered with a sterile aluminum container may be carried into the surgical field at the time of operation and placed in sufficiently close proximity to the cancer bed to enable massive doses to be applied in a short time, makes this procedure practicable without danger of high-tension shock.

Localization of Foreign Bodies.—The war and its consequent surgery have stimulated progress in the localization of foreign bodies. Many methods of localization have been devised, most of them with merit, and almost every individual group of surgeons and roentgenologists who have worked together have employed their own modifications of these methods. Early efforts were made in the A. E. F. to standardize methods of localization, and within reasonable bounds this was accomplished. Of course, it is primarily recognized that the type of localization work that must be done must conform to the type of surgery done; for instance, the localization work done during the "push" in an evacuation hospital was necessarily not the type of localization that was employed at a less active Base Hospital, where a different type of surgery was practised. The localization work done in the War Zone necessarily conformed to the type of surgical procedure, *e. g.*, in the front areas, where débridements were the rule, the complete tract of the missile being excised, and where every wound was considered an infected wound, the type of localization was quite different and frankly less exact than when the foreign body was removed by counterincision or by a secondary operation through a small incision where the surgeon was working in sterile tissues. It will never be possible to take any one method of localization and make it cover all the needs that one will encounter. One must select a method that will fit the existing conditions. It is safe from a surgical standpoint to divide localization methods into those which will be employed in emergency surgery and those that will be used where the time factor is not essential. From the roentgenologist's standpoint there are three types of localization methods:

(1) Those methods where a mark on the skin and a depth measurement afford the essential information which the surgeon desires.

(2) Intermittent fluoroscopic control where the roentgenologist gives the surgeon the necessary information as to depth and direction during the course of the operation.

(3) Those methods which employ a compass or some other instrument for directing the surgeon both as to depth and direction to seek the foreign body.

The indications for a choice of the above methods: Group 1 or those methods which employ only a skin mark and depth measurement as a rule are methods whose use is almost entirely limited to the extremities or to superficial foreign bodies. Group 2 or intermittent fluoroscopic

control applies best to multiple foreign bodies or foreign bodies in loose or movable tissues where the position of the foreign body is liable to change of position, as in the lungs or abdomen. Group 3, or compass methods, are indicated for foreign bodies in the mediastinum, heart, abdominal viscera, and brain where careful dissections and a minimum of trauma are essential. Compass methods cannot, as a rule, be used with intrapulmonary foreign bodies. For the use of compass methods those cases must be chosen in which there is no likelihood of change in the position of the foreign body.

In determining the depth of a foreign body from surface by *x*-ray methods use is made of triangulation, *i. e.*, if two sides of a right-angle triangle are known quantities, it is quite simple to determine the third. The unknown third arm of our triangulation always represents either the depth of the foreign body from the skin or furnishes the necessary data from which the depth is computed.

All of the methods and the numerous modifications which have been developed are basically founded on this principle, and consist chiefly in cleverly arranged mechanical and automatic methods of arriving at the unknown third side of the triangle. The aim of each worker has been simplicity, rapidity of application, and exactness.

Methods for Depth Measurement.—This may be done by a single plate method which consists in making two exposures on the same plate, the second exposure having been made after shifting the tube a known distance. This is illustrated in Fig. 617, where A1 and A2 represent the two positions of the tube, R1 and R2 the respective images of the foreign body on the plate, and P the foreign body. The same determination may be made fluoroscopically (Fig. 618), where A1 and A2 represent the two positions of the tube with a known tube shift distance, and R1 and R2 represent grease pencil marks made on the glass of the fluoroscopic screen, and P the foreign body. It is assumed in both instances that the distance from the tube to the plate and screen is a known quantity.

Of the simple methods of depth measurement easily the most popular and generally used has been the method of Strohl, which commends itself for its simplicity, ease, rapidity of application, and its relative exactness (Fig. 619).

The necessary mechanical parts consists of a prone fluoroscope with two parallel wires suspended at a known distance from the focal point of the target of the tube. The wires are arranged in such manner that the distance between the two wires, which are parallel, is such that they are separated from each other by a distance which is either two or three times the distance of the wires from the focal spot. Three is a better factor than two. Once this mechanical feature is adjusted, it remains fixed. In determining the depth of the F. B. it is only necessary to register its image on the fluoroscent screen superimposed on one of the parallel wires. Having done this, a mark is made with a grease pencil on the glass of the screen at the point where the wire touches the F. B., then rapidly shifting the position of the tube until the second of the

parallel wires is superimposed on the foreign body a second mark is made on the screen. Then, by measuring the distance between the two marks and multiplying by the factor 3 the result gives the depth of the foreign body. If the screen is not in contact with the skin the error for this must be deducted from the gross result.

For the method of the localization and extraction of foreign bodies, known as "intermittent control," we are indebted to Ledoux Lebard and Ombredaune. This method, devised during the early years of the

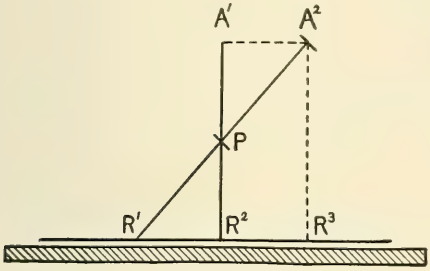

Fig. 617.

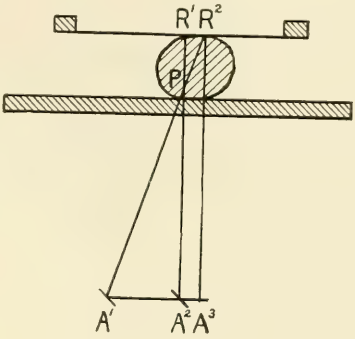

Fig. 618.

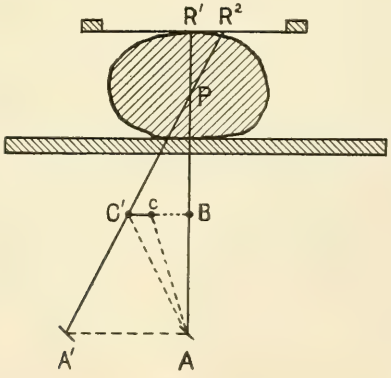

Fig. 619.

Fig. 617.—Plate Triangulation.
Fig. 618.—Fluoroscopic Triangulation.
Fig. 619.—Strohl Method of Triangulation.

war, grew in popularity, and by the time of the armistice it was in general use throughout the Service de Sante of the French Army and had grown very popular in the A. E. F. Many modifications of the original technic of Ledoux Lebard crept into use. Briefly this method is as follows:

The apparatus consists of a plain aluminum top table, on the floor beneath this table is a box on casters, which carries the *x*-ray tube. The surgeon works on one side of the table and the roentgenologist on the opposite side (Fig. 620).

The roentgenologist works with one sterile hand in which he holds a long indicator which has a curve just proximal to the tip. With his opposite hand he manipulates the position of the tube and the diaphragm. The roentgenologist works with a Diessane bonnet on his

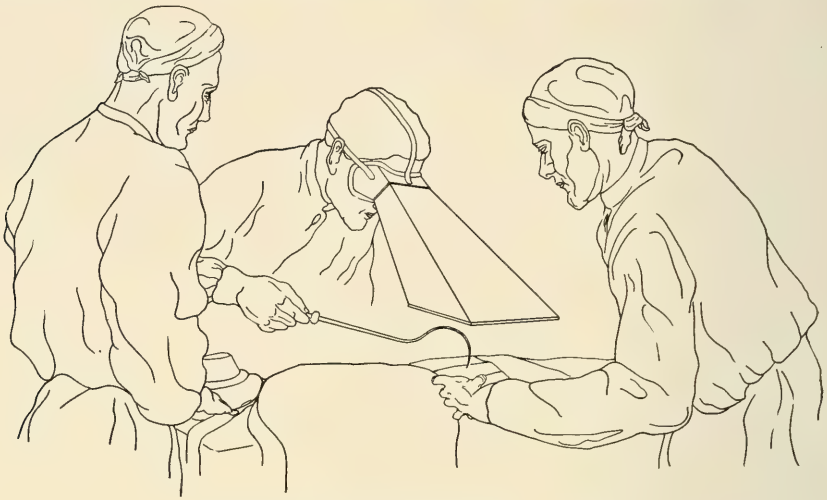

FIG. 620.—INTERMITTENT FLUOROSCOPIC CONTROL.

head (Fig. 621). The operative field must always be sterile. The roentgenologist, having indicated with his pointer the surface locations of the F. B., with his indicator the surgeon proceeds with the operation, stopping at intervals to be directed by the roentgenologist as to the direction and depth of the foreign body.

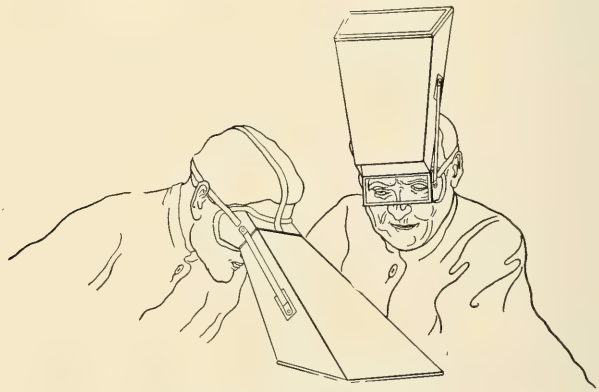

FIG. 621.—DIESSANE BONNET.

Compass Methods.—The devices are adjusted to marking on the skin prior to the operation. They have a center rod or pointer which when lowered to a set depth through the route of approach to the foreign body should just touch it. The compasses of Blake, Zaissi, and Hirtz are the best examples of this method. It must be understood that the

technic for the adjustment of such apparatus is complicated and time consuming, and that the method is only applicable where the time factor is unimportant. Probably the least complicated of these methods is the fluoroscopic Hirtz compass method. The graphic method for the adjustment of the Hirtz compass is very complicated, but probably furnishes the acme of refinement in compass methods.

Several of the French surgeons have devised a technic for the late removal of foreign bodies through small incisions under fluoroscopic guidance. The methods of Petit de la Villeon and Bec are probably the best known. Petit de la Villeon's method is for the late removal of intrathoracic foreign bodies through a small incision. Having the patient anesthetized, a small stab incision is made at a mark on the skin, showing the location of the foreign body. The patient is strapped

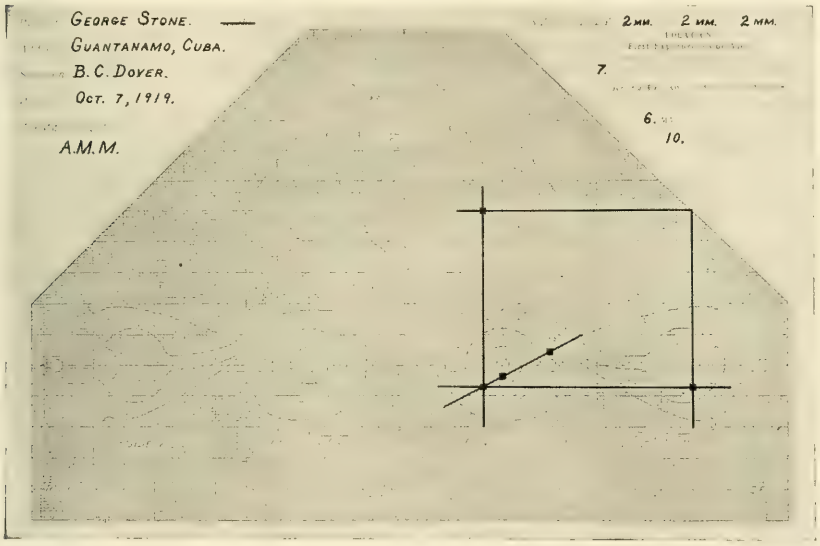

Fig. 622.—Eye Localization Graph. (Sweet.)

to the aluminum top of a table which is ingeniously devised so as to turn the patient for various oblique fluoroscopic views. Through the incision a pair of long-handled forceps is thrust, and under fluoroscopic guidance the forceps is forced by blunt dissection to the foreign body, which is grasped and removed. This method was criticised by another school of French surgeons, who condemned the method because of the danger of blunt dissection and the possible injury to blood-vessels from the sharp cutting edges of foreign bodies. A prerequisite for the use of such methods is a complete familiarity with screen images and the dexterity of manipulation under screen control that only comes with prolonged experience.

Eye Localization.—The ingenious method devised by Sweet has grown to such popularity in America that his methods are used almost entirely to the exclusion of the foreign system. Figure 622 shows the

finished graph as it is sent to the surgeons; and furnishes an exact working basis for the extraction of the foreign body.

The *x*-ray technic furnishing the information for the construction of the graph is somewhat complicated, and infinite care is necessary for an accurate result. For the *x*-ray technic the reader is referred to the U. S. Army *x*-Ray Manual.

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CHAPTER LVI

ELECTRODESICCATION AND ELECTROCOAGULATION METHODS IN SURGERY*

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Fulguration is a term which has been erroneously applied to all types of high-frequency currents or sparks for destructive action upon tissues. The fulguration method, originally described by de Keating-Hart (see Keen's Surgery, Vol. VI), *does not destroy tissue*. By this method long tension sparks are applied to the open field immediately after surgical ablation in malignant disease for the purpose of "altering nutrition," and in this way influencing cancer cells, but not for the least destructive action. It is claimed by de Keating-Hart that in his cases the percentage of recurrences was less than when operative surgery was employed alone. The value of the fulguration method has not been verified by others and has fallen into disuse. The present chapter will deal with the more potent destructive high-frequency currents. Hence, the misleading and erroneously applied term "fulguration" will be discarded, and the more appropriate and descriptive terms for the two effects of practical utility, "desiccation" and "coagulation," will be substituted.

The **electrodesiccation** method is one by means of which benign or malignant growths of small or moderate size may be destroyed by the utilization of heat of just sufficient intensity to desiccate or dehydrate the tissues. It is produced by a monopolar high-frequency current of the Oudin type, and is applied to the lesion by means of a steel needle or other pointed metallic applicator. The desiccation effect, originally described by myself, was produced by a high-tension static current transformed into a high-frequency current by means of Leyden jars and a resonator. Since the advent of modern transformer types of high-frequency machines, however, it has been found that the desiccation effect can be produced from the latter apparatus. This is an advantage, since static currents are influenced by atmospheric conditions and are often not available in humid weather. High-speed static machines are also expensive and occupy much room; hence it is an advantage to surgeons that the less expensive and smaller high-frequency machines may be used for desiccation work, since they are not influenced by atmospheric conditions. A meter cannot be used to measure this current. The proper current strength to destroy growths of different types and sizes must be estimated, but with practice this can be done

* Supplementary to Chapter XCVI, Vol. VI, p. 136.

without difficulty. A small growth may be desiccated through a sheet of white paper without charring or discoloring the paper.

The electrodesiccation method is of advantage when the lesion is localized and a good cosmetic result is desired. It is subject to such control as to area and depth that a very small growth, even on the cornea, may be successfully treated without impairment of vision by scar tissue. A growth on the vocal cords may be destroyed without impairing phonation. The very slight trauma and little secondary inflammation explain from a pathologic standpoint the slight scarring and the success obtained in treating these delicate structures. The Oudin current from which desiccation is produced is of relatively high voltage and low amperage.

Electrocoagulation is produced by a bipolar high-frequency current of the d'Arsonval type. It is more penetrating and intense in action than the desiccation method, and is utilized to destroy larger growths, including those which involve bone. There are many variations of technic in the application of both methods to suit the requirements of the individual case, which may not be considered in detail since sufficient space is not available. It may be stated, however, that the active electrode employed should always be pointed, such as a steel sewing needle; or, if not long enough, a steel knitting-needle, or stiff wire, which may be cut to any length and curved over a flame, so that it can be adapted to different anatomic locations. It makes no difference what metal is used, since the effect of high-frequency currents is entirely thermic and not electrolytic. It is not possible thoroughly to insulate these electrodes; hence care must be taken not to touch any tissues except those to be treated. A slight insulation may be accomplished by wrapping adhesive plaster around the needles. The indifferent electrode may be made of any material that will conduct electricity, such as a metallic plate, a moistened asbestos pad, and wet towels. One of these should be placed on the patient's back.

Both the active and the indifferent electrodes are connected with separate, insulated wires, one to either side of the d'Arsonval winding of the high-frequency machine. A meter may be used to regulate the current strength which varies, according to the size of the growth to be treated, from about 200 to 3000 milliamperes. Doyen's method of employing electrocoagulation was to use a blunt metallic electrode upon the growth and another electrode of the same type at some point near the growth, but the control of this method is imperfect, and experience has taught that the pointed electrode and the large pad on the back is a much superior method of application. The needle may just touch the surface of the growth, or be inserted into it while the current is passing, depending upon the depth of destruction desired. A metal snare may be used as the active electrode in the case of pedunculated growths. The d'Arsonval current from which coagulation is produced is of relatively low voltage and high amperage. If the active electrode touches the growth, no spark will be produced, but the tissues will be deeply coagulated, nevertheless. If a short air space intervenes between the

growth and the needle the current will be conducted to the tissue in the form of convective sparks, and the coagulation will be superficial.

The heat from high-frequency currents, unlike that from the galvanocautery, is not transmitted by contact, but is generated within the tissues by the resistance offered to the current. The galvanocautery, though having many important uses in surgery, is comparatively superficial in action, while the high-frequency current, under proper conditions, will penetrate and destroy tissues to any depth in parallel or divergent lines, depending upon the size and arrangement of the electrodes, and also the strength and quality of the current. These are varied to suit indications.

The aim with both the desiccation and the coagulation methods should be to destroy a growth at a single operation. But to be able to do this judgment must be acquired by experience, as no rule can be given that can be an infallible guide. When growths on cutaneous surfaces are destroyed by either method, they are usually cureted away immediately upon the conclusion of treatment. If necessary the base may receive further treatment; but, in the case of growths of mucous membranes (with some exceptions in the judgment of the operator), they are allowed to slough because of the greater danger of secondary hemorrhage. Bone will sequestrate in about five weeks after treatment.

The majority of high-frequency machines made by reputable manufacturers are suitable for the generation of currents for desiccation and coagulation. The difficulty lies principally in the acquirement of the proper technic of application, but this is not very intricate, and any surgeon who has seen the methods demonstrated and devotes the same time in practice as he would with any new surgical operation should do good work.

Among the **benign** surgical lesions involving cutaneous surfaces, mucous orifices, or osseous structures, which may be treated by the desiccation and coagulation methods with superior cosmetic results, are: Papillomas, fibromas, lipomas, sebaceous cysts, simple or pigmented moles, nevi, tattoo and powder marks, angiomas, lupus, chancres, chancroids, tuberculous or other ulcers, leukoplakia, erosions of the uterine cervix, Paget's disease, chondromas, exostoses, pterygium, leukoma, hemorrhoids, surgical tonsils in adults, localized infections of every type; indeed, any accessible benign growth or lesion, where destruction of tissue is indicated, is amenable to this treatment.

These electrothermic methods may not always be the best methods of treating some of the foregoing benign lesions, but they may be considered as an addition to the surgical armamentarium. In some of these lesions electrothermic methods may be considered superior to operative surgery, or, indeed, any other method. In other lesions they may be worthy substitutes in case of contraindication to operative surgery. As to this, judgment must be left to the surgeon. When growths in the bladder, larynx, esophagus, etc., are to be treated, suitable operative endoscopes must be employed to expose the growth. The same rules for local or general anesthesia apply as in operative surgery.

When the growth is small and superficial the desiccation method should be used; when large and of considerable depth, the coagulation method should be employed.

The electrothermic methods described have an important field of usefulness in the treatment of **malignant disease** of every type in accessible anatomic regions. The efficiency of these methods is increased in some cases by the judicious combination of operative surgery, radium, and the *x*-rays. When these electrothermic methods are used alone the malignant lesion must be localized.

The **basal cell** or rodent ulcer type of **epithelioma,** occurring on cutaneous surfaces, such as the face, eyelids, etc., even though advanced and with involvement of bone, is so satisfactorily treated by the desiccation or coagulation methods that these cases practically all get well when treated thoroughly. This conclusion has been reached after observation of the results of treatment of over 2000 cases of this type covering a period of twelve years.

In **squamous-cell** epitheliomas occurring in mucous membranes the chance of success is only slightly less than in the case of basal-cell epitheliomas, if localized; but, if metastasis has occurred, other methods must be used in combination, and the prognosis is less favorable.

These electrothermic methods are peculiarly adapted to the treatment of cancer within the mouth. Malignant tissue (including bone), occurring in any part of the oral cavity comprising the lips, buccal surface, tongue, floor of the mouth, alveolus, hard palate, antrum, tonsils, pharynx, epiglottis, larynx, and proximal end of the esophagus, may be destroyed with one electrothermic operation.

It is not necessary to split the cheek surgically to render a growth accessible to treatment, since the exposure secured by the use of a mouth-gag, cheek retractors, tongue depressors, traction on the tongue by means of a suture through it, tongue forceps, or by the use of an endoscope is sufficient to permit the destruction of a growth. A tongue may be coagulated to the base and then excised without hemorrhage.

To amputate a tongue by the electrocoagulation method ether anesthesia is employed. The ether should be removed from the room when the patient is fully under its influence before applying the current, else it might ignite. If necessary, the operation may be temporarily discontinued and ether administered as often as required, though usually this operation is of such short duration that the use of ether a second time is not necessary. After the jaws are separated by a mouth-gag, the tongue is drawn forward by means of a suture through it; a large asbestos pad, metallic plate, or whatever is used as the indifferent electrode, is connected by an insulated wire to one side of the d'Arsonval winding of the machine; a curved knitting needle, which has been cut to a suitable length, is fastened in an insulated handle, and this connected by another cord to the other side of the d'Arsonval winding of the machine. The needle is brought in contact with the anterior surface of the tongue as far back as is necessary, and the current is turned on either by the operator by means of a foot control or by an assistant

on signal. It is important that the current be turned on or off quickly as required for accurate control, also in case tissue not desired to be

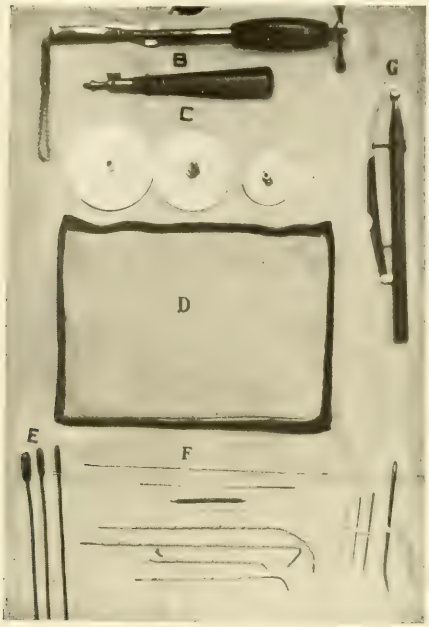


FIG. 623.—ACTIVE AND PASSIVE ELECTRODES USED FOR ELECTRODESICCATION AND ELECTROCOAGULATION.

coagulated is accidentally touched. The needle is then moved across the tongue and carefully inserted into it at different points as coagula-

A *B* *C*

FIG. 624.—*A*, BASAL-CELL EPITHELIOMA INVOLVING THE UPPER LIP, ALVEOLUS, HARD PALATE, NOSE, SEPTUM, AND ANTRUM. *B*, RESULT OF ELECTROCOAGULATION TREATMENT. NO RECURRENCE IN THREE YEARS. *C*, RECONSTRUCTED FEATURES BY THE SCULPTURE METHOD.

tion takes place, and in a short time the tissues of the tongue will be entirely coagulated. The tip of the tongue is then elevated by means of the suture through it, and a straight, sharp sewing needle of proper

length is substituted for the curved knitting-needle. The frenum is then coagulated and the needle inserted in the tongue through the floor of the mouth. When coagulation is completed, curved scissors may be used to cut through the coagulated area on the under surface of the tongue until it is separated back to the line that has been coagulated

A *B* *C*

FIG. 625.—*A*, BASAL-CELL EPITHELIOMA OF THE NOSE. *B*, RESULT OF ONE ELECTRODESICCATION TREATMENT. *C*, ARTIFICIAL NOSE BY THE SCULPTURE METHOD.

through on the anterior surface, when the tongue may be cut across until separated from its attachment to the base of the tongue. Blood-vessels encountered in the oral cavity are blocked by the current and secondary hemorrhage rarely occurs. After-treatment consists of simple antiseptic mouth-washes, and the application, two or three times daily

A *B*

FIG. 626.—*A*, ADVANCED BASAL-CELL EPITHELIOMA OF THE CHEEK AND INVOLVING THE BONES. *B*, RESULT OF ONE ELECTROCOAGULATION TREATMENT.
No recurrence in two years. Note regeneration of tissue and absence of contracted scar.

until clean, of dichloramin-T and chlorcosane (5 per cent. solution) to sterilize and deodorize. Care should be taken not to remove slough prematurely, else secondary hemorrhage may occur. The slough usually separates in from ten to fifteen days.

In addition to the desiccation or coagulation of tissues and the seal-

ing of blood- and lymph-channels, the heat penetrates beyond the area totally destroyed and devitalizes malignant cells without permanently impairing the healthy tissue, thus lessening the likelihood of local

A B

FIG. 627.—*A*, GLIOMA OF THE OPTIC NERVE OF FIVE WEEKS' GROWTH, FOLLOWING A PRIMARY SURGICAL ENUCLEATION, MEASURING 20 INCHES IN CIRCUMFERENCE. *B*, RESULT OF ELECTROCOAGULATION, EMPLOYING A SNARE AS THE ACTIVE ELECTRODE, THEN COMPLETE EXENTERATION OF THE ORBIT BY ELECTROCOAGULATION, A LONG SEWING NEEDLE AS THE ACTIVE ELECTRODE. CONDITION TWO MONTHS AFTER TREATMENT.

Patient died of spinal metastasis seven months after treatment, without local recurrence.

recurrence or metastasis and conserving the maximal amount of normal tissue. It is a demonstrated fact that malignant cells are devitalized at a lower degree of heat than normal cells, and this selective action of the heat from high-frequency currents has often been observed. In-

A B

FIG. 628.—*A*, BASAL-CELL EPITHELIOMA INVOLVING THE BULBAR CONJUNCTIVA, UPPER AND LOWER EYELIDS, CANTHUS, AND LATERAL ASPECT OF THE NOSE. *B*, RESULT OF ONE ELECTRODESICCATION TREATMENT.

Note absence of contracted cicatrix.

deed, there appears to be some regeneration of normal tissue after the use of these currents (Figs. 626, 628, 630, 631). In malignant tonsils, if there is a suspicion that the carotid artery has been coagulated through, ligation of this vessel should be practised about the tenth day. If this

were done at the time of the coagulation operation, collateral circulation would probably have taken place before the time for separation of the slough, and a hemorrhage might result in spite of the ligation. When the ligation is done about the tenth day, organization will have taken place before the collateral circulation is established, and the danger of secondary hemorrhage obviated.

A B C

FIG. 629.—*A*, CARCINOMA OF THE TONGUE. *B*, SHOWING CONDITION AFTER AMPUTATION BY ELECTROCOAGULATION. *C*, ANOTHER TONGUE AMPUTATED BY ELECTROCOAGULATION.

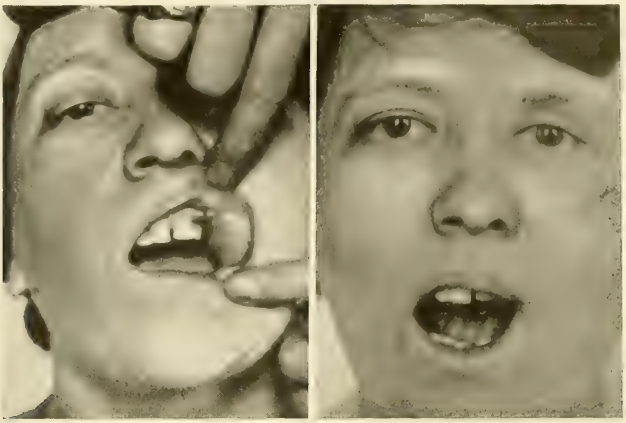
The success obtained by the use of the electrodesiccation and electrocoagulation methods in the treatment of malignant disease of various types is explained by the fact that the malignant tissue was all destroyed, and, when possible, with one radical treatment, while at the same time the blood- and the lymph-channels were sealed. In cases in which, by error of judgment, some of the diseased tissue was not

A B

FIG. 630.—*A*, EPITHELIOMA OF THE LOWER LIP. *B*, RESULT OF ONE ELECTRODESICCATION TREATMENT. FREE FROM RECURRENCE THREE YEARS.
Note absence of contracted cicatrix and regeneration of normal tissue.

destroyed, recurrence was the rule; indeed, owing to stimulation by the electric current, the disease often manifested greater activity than would have been the case if left untreated. In cases of recurrence, however, the electrothermic methods have often been applied twice, or even a number of times, before final success was attained. The practice of

intentionally treating a malignant lesion by a series of desiccation or coagulation operations is a reprehensible one, and must be discouraged in no uncertain manner. It is quite as irrational to do this as to excise



A *B*

FIG. 631.—*A*, ANGIOMA INVOLVING BUCCAL SURFACE, UPPER AND LOWER LIP, ANGLE OF THE MOUTH. *B*, RESULT OF ELECTRODESICCATION TREATMENT UNDER LOCAL ANESTHESIA.
Note absence of contracted cicatrix.

a cancerous growth surgically in a series of operations with the hope of success. This is mentioned in view of the fact that some physicians have made it a practice of intentionally treating cancer in a series of

A *B*

FIG. 632.—*A*, ELEVATED, PIGMENTED NEVUS OF THE FOREHEAD. *B*, RESULT OF ONE ELECTRODESICCATION TREATMENT UNDER GENERAL ANESTHESIA.
Note absence of contracted cicatrix.

electrothermic applications without success, and the reputation of the method has unjustly suffered.

Knowing the potency of the electrodesiccation and electrocoagula-

tion methods, it is for the surgeon to decide whether he will use them in suitable cases of cancer of the breast, uterus, rectum, prostate, bladder, or even in the peritoneal cavity, alone or in combination with surgery or other methods. It is emphasized that an accessible growth of any size may be destroyed by the electrocoagulation method.

A few illustrations of the electrodes used and the results of these methods are appended (Figs. 623–632).

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CHAPTER LVII

THE SURGERY OF THE INFECTIOUS DISEASES*

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Abscess of the Lung.—Reliable figures indicating the frequency of occurrence of abscess and gangrene of the lung as a result of war conditions and war injuries are not yet available. Abscess of the lung is not an uncommon sequel of gunshot and other injuries of the chest. Associated injuries of the chest lower reparative power in all parts of the body. The infection nearly always present and the disturbed circulation in open wounds of the chest favor the development of abscess and gangrene of the lung.

A most enlightening observation is referred to by Hughes and Banks, in their War Surgery, p. 506, that explains a cause of pulmonary engorgement and cardiac embarrassment that may perhaps be operative more frequently than has been appreciated:

"A man had a large piece of his left thoracic wall and part of his sternum carried away as the result of the bursting of a trench mortar. The pericardium and lung were exposed, and the main feature in his case was cardiac embarrassment. He was given an anesthetic prior to dressing the wound, as there was severe hemorrhage from the internal mammary artery. It was then ascertained that although the lung was exposed, yet it was inflated at each inspiration, and the immediate trouble was due not to the pulmonary condition, but to cardiac displacement. The displacement was of a rotary character, the apex of the heart having moved to the right and forward. This was quite sufficient to bring about an amount of obvious kinking in the pulmonary veins, with consequent engorgement of the affected lung."

The lung is elastic and not easily fissured by a missile. A small missile may give rise to few or no symptoms. It may become surrounded by a thin sac wall, and the surrounding pulmonary tissue remain freely movable and elastic. Occasional local pain and a little dyspnea on exertion is sometimes complained of, and would seem in some cases at least to be due to the scar tissue extending from the chest wall to the spot in the lung where the missile is lodged. Abscess rarely develops in cases in which there is an associated hemothorax.

The contents of the abscess, offensive in character, are sometimes coughed up together with a small amount of blood. Spontaneous cure may result. The chief dangers are septic pneumonia and gangrene.

* Supplementary to Chapter LXXXII, Vol. V, p. 1101, and Chapter CLIII, Vol. VI, p. 993.

Gangrene of the Lung.—So far as indicated by figures already published gangrene of the lung as the result of gunshot wounds is comparatively infrequent, and particularly rare in cases of gunshot wounds of the lung associated with hemothorax. Gangrene may follow abscess, especially if a septic pneumonia develops. It may result from emboli arising in gangrene of the Vincent variety in other parts of the body. In gangrene of the lung emboli may be disseminated. Hughes and Banks, War Surgery, 1919, p. 518, report a case in which an embolus lodged in the penis, giving rise to a constant painful erection until the organ became one gangrenous mass. The patient died.

Pneumococcus Infection.—These were considered at some length in Volume V of this work. Since then our knowledge of the pneumococcus and its associates has expanded, but cannot by any means be said even yet to have reached finality.

The observations of Dochez and Gillespie have shown four strains of pneumococci, and these can be distinguished by specific agglutination.

Types I and II are the common cause of lobar pneumonia.

Type III is regarded by many as identical with the Streptococcus mucosus, but about this some uncertainty exists. It is very virulent.

Type IV may again be divided into several subdivisions, and seems to represent relatively avirulent and even saprophytic forms.

The pneumococci are closely related to the streptococci, and Rosenow concludes that they are mutally transmutable. This needs further corroboration. The rôle which the various strains play in surgical pneumococcus infections has not been worked out satisfactorily and deserves investigation.

Many cases of pneumonia are mixed pneumococcus and streptococcus infections and they are apt to be more severe with less tendency to healing. From the surgical standpoint it is interesting to note that pleurisy caused by mixed infections or by streptococcus or staphylococci alone show less tendency to resorption of the exudate (Netter, Renvers, Levy, Vierordt).

It is of further surgical interest that pneumococcus arthritis, unlike gonococcus arthritis, involves several joints, preferably the knee, the shoulder, and the small sternoclavicular joint. The joints may become involved during an attack of pneumonia or even during convalescence. The infection extends beyond the joint to the periarticular tissues. The exudate is purulent. The prognosis, however, is favorable and motion may not be seriously impaired (Vogelius).

Important is the Pneumococcus endometritis (Weichselbaum) which occurs during pregnancy and the puerperium.

The pneumococcus is of further importance surgically in osteomyelitis, orchitis, tenovaginitis, strumitis, and pyemia. The exudate of pneumococcus infection is generally creamy and purulent, but clear.

Surgery of the Puerperium.—Our understanding of the relationship between the pelvic organs of generation and the kidney has been advanced by the recent work on the lymphatic distribution to the kidney, ureter, bladder and broad ligament, and colon. There is an in-

timate connection between the lymphatics of these structures and the kidneys, and through the capsule to the perinephric tissue. These researches are important from the surgical point of view.

Generally speaking, the lymphatics accompany the blood-vessels. They form a capillary network in the cortex surrounding the tubules like the blood-vessels, but they do not enter the glomeruli. The lymphatics of the cortex communicate with those of the capsule. The lymphatics empty into the efferent lymph trunks which accompany the renal vessels to the hilus (Müller).

It is stated that they form arches at the juncture of the cortex and medulla, just as the vessels do. It must be said, however, that in view of the totally different conception of the blood circulation of the kidney, as recently established by Gross, this view may be questioned, and needs renewed investigations.

The connection between the lymphatics of the bladder, ureter, and kidney is through the lymph-channels of the muscular coat. These, as well as the lymphatics in the outer fibrous coat which pass to the regional lymph-glands, are largely perivascular. According to Eisendrath and Schultz the lymphatics of the upper third of the ureter communicate through lymphatics in the submucous coat of the renal pelvis with those of the kidney at the juncture of the papillæ with the pelvis. Thus is established intimate connection between the bladder, ureter, kidney, and perinephric tissue through the capsule. Moreover, lymphatic anastomoses are said to exist between those of the broad ligament and the ureter and between the colon and the kidney.

Surgical Complications of Influenza.—That *empyema* is a not uncommon complication of influenza and influenzal pneumonia is the experience of all physicians who have had many cases to deal with. Many excellent papers have appeared in medical journals discussing the treatment, and the reduced death-rate that has followed an improvement in technic. (For further details the reader is refered to the article on Empyema, p. 396.)

A feature of some cases—fortunately not very many—has been the extreme toxicity, a *septicemia* with acute abdominal symptoms, pain in the extremities and multiple phlegmons, ending in death in a few days.

Quite distinct from the multiple phlegmons occurring in influenzal septicemia are localized and generally single *abscesses*, occurring on different parts of the trunk and on the extremities. Sometimes they develop in the neighborhood of joints, in the periarticular tissues; occasionally, but fortunately very seldom, they perforate the joint capsule and infect the joint cavity. When the germ is a pneumococcus the prognosis is good. A perfect or nearly perfect functionating joint is the end-result. In the treatment passive hyperemia is often very useful.

On the trunk abscesses may form about the shoulder, the chest, and abdomen. Cases of abscess in the sheath of the rectus abdominis are reported by Gage (Annals Surg., Aug., 1919). They seem to develop

preferably about the lower end of these muscles. Their formation is characterized by pain, tenderness, and swelling, but no redness. The prognosis is good.

Wolbach reports a series of cases in which *hemorrhages* were found in the recti muscles at autopsy. They vary in size from small infiltrations to large masses of blood-clot separating fibers longitudinally and occupying spaces between transverse tears of the muscle.

There seems in some cases to be a Zenker degeneration of the muscle. Is there a definite selective action on the part of the different organisms or different varieties of the same organism for different tissues as claimed by Rosenow?

Next in frequency is the involvement of the *middle ear*, the *mastoid*, and the *sinuses*. Influenzal otitis is characterized by severe constitutional depression and a lowered resistance of the individual which allows the infecting organisms to make rapid headway. Another characteristic of influenzal otitis is the presence of small blood vesicles on the drum membrane. The discharge in acute cases is apt to be profuse and blood stained. The constitutional reaction may be severe with fever persisting for five or ten days, and early operation indicated.

In some cases, however, the reaction is trifling and deafness may be the only subjective symptom. Some time later there may be headache or chill, or some other symptoms of an intracranial complication, and on examination there is found evidence of a latent mastoid suppuration. These latent cases were formerly regarded as occurring only when the infection was due to the Streptococcus mucosus capsulatis, but this organism has not been found in all cases, and it would seem that such latent types of the disease may be due to various organisms. These cases are particularly liable to go on to intracranial complications unless appropriate treatment is promptly carried out and an early mastoid drainage established.

The occurrence of *suppuration of the nasal accessory sinuses* is common in all influenzal attacks. In many cases there is a profuse nasal discharge, and in others is indicated only by severe neuralgic headaches. It is unusual for the acute cases to require surgical interference, but the need of this may arise, as in any acute sinus suppuration. They usually, however, subside under proper endonasal treatment. It is common to have these patients present themselves complaining of headache or retro-orbital pain a week or more after an attack of influenza. On examination they are found to be suffering from an infection in some sinus. The presence of nasal discharge may not be noted by the patient, as it is not uncommon in such cases for the discharge to be small in amount and to pass into the nasopharynx. If associated with pneumonia the same organisms are usually present that are found in the lung.

With regard to the *throat complications* in the recent epidemic, there was nothing very characteristic. In some cases there was a very acute laryngitis calling for intubation. The symptoms of an influenzal attack are usually severe in children with adenoids and enlarged tonsils.

Peritonitis.—In some cases of influenzal pneumonia the early symptoms suggest the onset of acute peritonitis rather than an intrathoracic lesion. The same is occasionally seen during the onset of pneumonia when there is no epidemic of influenza. This peculiar condition has been observed in children and in adults. A careful observer will generally, however, note a disturbance of the respiratory rhythm, although no physical signs of pneumonia may be discovered for twelve to twenty-four or even thirty-six hours. In some instances during the late epidemic of influenza a diagnosis of appendicitis was made and the appendix removed.

There do occur, nevertheless, cases of purulent peritonitis for which at operation or at the necropsy no other cause can be discovered than the influenza bacilli or a variety of streptococci or pneumococci. Abdominal drainage in such cases may prove of service by relieving intra-abdominal tension and thus restoring the circulation in the blood- and lymph-vessels.

It must always be borne in mind that acute *appendicitis* and appendicitis with perforation may occur during an attack of influenza.

The differential diagnosis is sometimes difficult, but can generally be made correctly by a careful study of the clinical history and symptoms.

Typhoid and Paratyphoid Fevers.—The history of preventable diseases in armies during the war is full of interest, and is really a history of preventive medicine. If our profession could give no other reason for its existence than its accomplishments in this one fields, it might with pride rest on the laurels won in preventing preventable disease in the armies of the world. Perhaps the most important of all is the typhoid group.

The first case on record in England which allows of clear demonstration is that of Henry, Prince of Wales, eldest son of King James I, who died in 1612 during a fever epidemic at that time. In 1643 Thomas Willis, whose name is so familiar to us from the anastomosis of the main cerebral arteries at the base of the brain, gives a classical description in "De Febribus" of an epidemic among the King's followers in the royalist stronghold at Oxford that was, without doubt, typhoid fever.

In the American Civil War there were 79,462 cases of typhoid and 29,336 deaths, a death-rate of 37 per cent. In the Boer War there were 58,000 cases of typhoid and 8000 deaths, a death-rate of 14 per cent., and in the Spanish-American War 20,738 cases of typhoid and 1580 deaths. Nearly one-fifth of the entire army suffered from the disease (Keen, Medical Research and Human Welfare, Houghton, Mifflin Co., 1917).

The medical statistics of the armies of the Allies are not yet available, but it is known that so far as concerns preventable diseases, and particularly the typhoid group, the figures are in large measure very encouraging. Mr. Forster on March 1, 1917 stated in the House of Commons that "The last weekly return showed only 24 cases in the four British armies in France, Salonica, Egypt, and Mesopotamia.

The total number of cases of typhoid fever in the British troops in France down to November 1, 1916 was 1684; of paratyphoid, 2534; and of indefinite cases, 353, making a total of 4571 of the typhoid group. If the same ratio as obtained in the Spanish War in 1898 (1 in 5) had continued, there would have been in the British Army alone 1,000,000 cases. In the A. E. F., from June 15, 1918 to March 31, 1916 there were 143 deaths from typhoid and paratyphoid.

The surgical interest in the typhoid group relates especially to the influence of preventive inoculations on the complications and sequelæ and on the carrier problem. The mortality percentage is reduced as appears in the following table:

Disease.	No. of cases.	Deaths.	Mortality, per cent.
Typhoid—inoculated	821 } 1118	27 } 84	3.28 } 7.51
Typhoid—not inoculated	297 }	57 }	19.19 }
Para. A—inoculated	123 } 344	0 } 1	0.00 } 0.29
Para. B—not inoculated*	221 }	1 }	45 }
Para. A—inoculated	239 } 1038	1* } 18	0.41 } 1.68
Para. B—not inoculated	799 }	17 }	2.12 }

As affecting the incidence of hemorrhage and perforation of the intestine, the figures are not sufficiently large to give a definite answer, but they justify a hope that these serious complications are reduced in frequency. Although hemorrhage occured in 40 of the 297 non-inoculated cases (13.46 per cent.), yet there were only 67 in the whole series of 2500 cases (2.68 per cent.).

There were 14 perforations (0.56 per cent.), notwithstanding the fact that the great majority of the patients were between twenty and thirty years of age, during which decade perforations of the intestines occur most frequently. It is interesting to note that 3 of the 5 perforations occurring in the paratyphoid group were in the large intestine, which seems to be more seriously involved than in true typhoid. Perforation of the appendix occurred in one case of paratyphoid A, none of the paratyphoid perforation cases had been inoculated (Webb-Johnson, *loc cit.*).

The Army Medical services of the Allies have given attention to the carrier problem. The beautiful experiment by Professor Coplin shows one of the principal means of spreading typhoid in armies. "He made a fly walk across a plate of gelatin on which was growing a pure culture of typhoid bacillus, then he caused the same fly immediately to walk over the surface of a plate of sterile gelatin. This plate was then placed in an oven at a suitable temperature. Wherever the contaminated feet of the fly had touched the sterile gelatin there a colony of typhoid

* This patient had lymphosarcoma. Webb-Johnson, Surgical Aspects of Typhoid and Paratyphoid Fevers.

bacilli sprang up. The footprints of the fly were as evident as the footprints of a horse on a newly smoothed dirt road (see Fig. 633). Any fly which has walked over the infected excreta of a typhoid patient and then walked over the soldiers' or our own food carries the infection in like manner" (Keen, Medical Research and Human Welfare).

It is recognized in the army that all cooks and all those who handle and transport food should be demonstrated to be non-carriers. The absence of a history of never having had typhoid is not enough. Some typhoid carriers have never, to their knowledge, had typhoid. The disease in some carriers has been of such a mild form that nothing more than a temporary indisposition was noted.

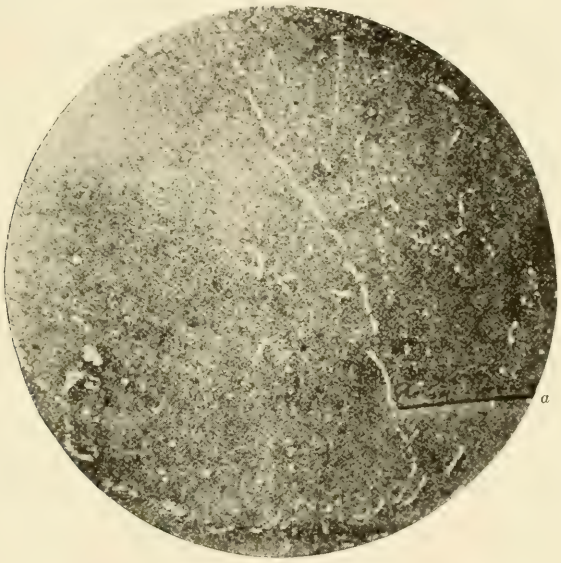

FIG. 633.—TYPHOID FLY TRACKS.

Note the left-hand interrupted line (*a*) and the almost parallel dotted line to the right of *a*. The first, *a*, was made by the left wing, the other by the right feet of the fly. Each of these lines represents a row of colonies of typhoid bacilli growing on sterile gelatin infected by a typhoid fly which had once walked over a culture of typhoid bacilli and then once over the sterile gelatin. (Keen's "Medical Research and Human Welfare," Houghton, Mifflin Co.)

The carrier problem is of interest to surgeons, because in some cases cure can only be obtained by surgical methods of treatment.

There would at present seem to be four sources of infection in typhoid carriers, the liver and bile-passages, the kidney and urinary tracts, the spleen, and the bones. Typhoid carriers are found in the class of those who during the disease have suffered from complications affecting the excretory channels.

Abscess of the liver is a rare complication. Although the organisms are excreted by the liver, the ducts are seldom involved in inflammatory action. Two sources of infection are recognized—through the hepatic artery and the portal vein. The clinical picture when the infection is through the hepatic artery is that of a general septicemia. The source of infection delivered to the liver by the portal vein is usually a gangren-

ous appendix with associated thrombophlebitis. An abscess of some size may result from the coalescence of several smaller ones. Venema (Bul. Kl. Wochen., 12, 1907) reports a liver abscess through typhoid ulceration of the bile-ducts.

Of greater surgical interest is the relation of the gall-bladder to the carrier problem. Typhoid bacilli are constantly found in the bile contained in the gall-bladder during the course of the disease, and sometimes for many months afterward. They may be brought by the blood-vessels supplying the gall-bladder, but the liver is the common and known source of supply. The liver does not kill all the organisms. Its own efficiency may be lowered by parenchymatous degeneration. The walls of the gall-bladder do not always escape, and cholecystitis with or without gall-stone formation may result. In an investigation of typhoid fever in the Rhine province it has been observed that a large proportion of all persons suffering from gall-stones were discharging typhoid bacilli (Jordan, General Bacteriology, 1918, p. 309). Perforation has occurred in a number of reported cases. Under what conditions typhoid bacilli continue to grow and multiply in the gall-bladder long after they have disappeared from the systemic circulation is not yet understood. After the removal of the gall-bladder typhoid bacilli disappear from the stools.

There are exceptions to this statement, however, in those cases where the organisms continue to be found in the stool after a cholecystectomy. We must look to the spleen and bone-marrow as a probable source of supply. Three intestinal carriers reported by Nichols, Simmons, and Stimmel (Jour. Amer. Med. Assoc., Aug. 30, 1919) were cured by cholecystectomy, and two remained intestinal carriers after the gall-bladder had been removed.

That the urinary system may render a man or a woman a typhoid carrier is being recently established. Nichols, Simons, and Stimmel (*loc. cit.*) report the case of a man aged twenty-one, white, a cook, who was found in a routine examination of food handlers to be a urinary typhoid carrier. He had had a prolonged attack of typhoid six years before. Since May, 1916 he had had eight typhoid inoculations, the last three being in January, 1918. Left nephrectomy was performed. The kidney showed a marked grade of hydronephrosis. The contents of the pelvis consisted of a thin turbid fluid containing leukocytes and a pure culture of typhoid bacilli. He was returned to limited service duty in good condition.

In some cases there is a descending infection. The bladder becomes infected. Cystitis develops. The infection may extend to the epididymus and testicle, with abscess formation. The typhoid bacilli have been recovered from the recesses of the prostate, from the seminal vesicles, and from the urethral crypts. Prostatitis and prostatic abscess have been observed in typhoid, although the typhoid bacilli have been found in the pus of a prostatic abscess.

The spleen is active in removing the infection from the blood in all protozoal diseases. In fulfilling this function in the typhoid group it

commonly becomes enlarged. It would appear that occasionally the spleen fails partially in its work of abstraction and itself harbors the bacilli. Infarcts occur with abscess formation and typhoid bacilli are found in the pus. To rid the body of persistent infection in malaria Jonnesco removed the spleen (Jonnesco, Bull. et Mèm. Soc. chir., Bucharest, 1901–02, iv, 58), and for the same reason Mayo removed the spleen in syphilitic and pyogenic infection (W. J. Mayo, Lancet, Nov. 25, 1916).

Can a man vent his spleen on his neighbor in more than a poetic sense?

In Webb-Johnson's series (*loc. cit.*) there were 5 cases of obvious bone disease. "Four of them occurred in typhoid and one in paratyphoid B. and four of the five were in non-inoculated individuals." "There were four instances of the ribs being affected and one of the tibia, apart from those of pain in the tibia, in which there was no objective sign of the disease." Typhoid osseous necrosis is generally cortical, rarely central, and consists of resorption, liquefaction, and formation of typhoid granulation tissue, but with little tendency to suppuration. The tibia, femur, and bones of the head, especially the frontal bone, are often affected. They are generally clear-cut lesions without new bone formation, unlike syphilis, in which bone destruction and bone regeneration go hand in hand.

Typhoid bacilli are found in the bone-marrow during the disease, and may remain latent for a long time. Abscess may result as long as seven years after convalescence (Buschke, Fortsch. d. Med., 1894, 573). They may become active at any time under favorable conditions. We must then place the bone-marrow under suspicion, together with the spleen and gall-bladder, in those individuals showing a persistence of infection after recovery from the typhoid group of diseases.

In the majority of the cases of lingering infection in the gall-bladder, spleen, kidney, and bone-marrow the recuperative powers of the individual alone or aided by modern therapeutics, fortunately, are successful in ridding the system of the typhoid group of organisms. In the smaller group, in which medical and hygienic measures fail, surgery offers relief. The results in those cases submitted to cholecystectomy and nephrectomy have been, in the main, satisfactory, and even splenectomy may yet be considered as a legitimate means of removing a persistent infection.

Cases of meningitis and brain abscess associated with typhoid fever have been reported by Keen and others; and McClintock, a case of brain abscess in which typhoid bacilli were found (Amer. Jour. Med. Sci., 1902).

CHAPTER LVIII

ETHER ANESTHESIA

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THE BASIC LAWS OF THE VOLATILE ANESTHETICS

The extremely rough quantitative methods generally used in surgical work in the administration of ether, or, in fact, of any of the volatile anesthetics, have resulted in the erroneous conception among the medical profession that the anesthetic dosage is very variable. In truth, the action of ether under accurate dosage is most definite, and almost invariably the same degree of narcosis is produced by the administration of the same ether tension. In other words, this constant effect of the volatile anesthetics shows that their action is proportional to their concentration in the body—the law of mass action. It must be remembered that in dealing with a volatile substance the dosage does not depend on the mass of liquid evaporated, but rather on the concentration of its vapor, or specifically on the constancy of the volume percentage or tension of the ether vapor in the inspired air.

Paul Bert[1] in 1878, while conducting experiments to determine the physiologic effects of varying barometric pressures, demonstrated that narcosis from nitrous oxid is due to a certain degree of saturation of the tissues with the anesthetic; that this degree of saturation varies with every change in the partial pressure of the gas in the inspired air, and finally that the depth of the anesthesia is dependent on the partial pressure of the anesthetic vapor in the lungs.

This fact, that the intensiveness of the physiologic action of the volatile anesthetics obeys the fundamental and well-known physical-chemical properties of gases, has made possible accurate dosimetric methods for their administration in surgical narcosis.

Spenzer[24] and Rosenfeld[23] were the first to attempt to determine the strength of ether vapor necessary to produce narcosis in rabbits; using a rather crude method they found that the efficient dose for rabbits lies between 3.5 and 6 per cent. by volume; Dreser[12] obtained a similar figure for man.

Anesthetic Tension.—Recently very exact information on the percentage of ether necessary to produce surgical narcosis has been obtained by the use of the anesthetometer devised in 1913 by Dr. Karl Connell,[8] of Roosevelt Hospital, New York. With this apparatus Connell showed that the tension of ether vapor necessary to produce narcosis in man is about 50 mm. of mercury; allowing for the vapor pressure of water in the lungs this corresponds at sea level to 7 per cent. by volume.

By the use of this accurate apparatus Boothby,[2,3,5] in an extensive series of cases, confirmed Connell's work and found that the optimum dosage of ether vapor for man is between 47 and 53 mm.; he further demonstrated that individuals vary but slightly in their susceptibility to ether, and that in practically every case surgical narcosis is produced by the development and maintenance in the central nervous system of an ether tension of 47 mm.; this tension has been designated by Boothby as the "anesthetic tension" of ether vapor.

For physiologic work in which the reflexes are to be determined it is particularly important that an apparatus be used by which the dosage of ether can be accurately controlled. Mann,[18] using the Connell apparatus, has tested the vascular reflexes in dogs with various tensions of ether vapor, and found that the physiologic reactions under ether vary with remarkable constancy corresponding to the particular tensions used. He found that the lowest ether tension that will allow operative work in dogs is approximately 36 mm.; that any tension between 36 and 45 mm. is safe as regards the life of the animal, but that tensions between 48 and 50 mm. are liable to prove fatal. A dog probably cannot live under ether tensions above 60 mm. It is evident, therefore, that the anesthetic tension required for dogs is slightly lower than that required for man; and that the tension required for rabbits is possibly even lower than for dogs, as indicated by unpublished data collected by Boothby.

The evidence obtained by the administration of ether by an accurate dosimetric method conclusively proves that there is little or no variation in the anesthetic tension of ether required by man for surgical narcosis. How then can this data be harmonized with the equally correct clinical experience that some patients require by the ordinary methods of anesthesia more liquid ether poured on the cone than do others?

During the stage of induction there is a wide variation in the amount of air inspired by different patients. The inspired volume may vary from 2 to 20 liters per minute, depending on the size of the patient and the character of the respirations, and it must be remembered that the expired air passes through the mask as well as the inspired air, so that from 4 to 40 liters of air circulate through the mask for each minute. To bring the tension of ether in 40 liters of air up to the same tension as in 4 liters would obviously require ten times the amount of liquid ether. Even greater variation may be expected in the amount of liquid ether used because frequently a considerable amount is lost by running down the side of the mask on to the patient's face. Moreover, during the early period of anesthesia a stronger concentration must be administered in order that the central nervous system may become saturated up to the desired anesthetic tension as rapidly as possible. Boycott, Damant, and Haldane[6] have studied the rapidity of saturation and desaturation of nitrogen up to a pressure of 6 atmospheres. According to their calculation the body of a man would be half-saturated with the excess of nitrogen in twenty-three minutes, three-fourths saturated in forty-six

minutes, etc., the pressure remaining constant. They also point out that the rate of saturation and desaturation would vary in different individuals according to the relative mass of blood and the rate of circulation. In the same individual different organs would be more or less quickly saturated and desaturated, according to the relative volume of their blood-supply. If ether were substituted for nitrogen, it is probable that the rate of saturation would be nearly the same.

Therefore, the time requisite to saturate the body of an average patient up to the anesthetic tension of 47 mm. is theoretically between one-half and three-quarters of an hour, because during a part of this time a tension of 100 mm. can be administered, and during the remainder a tension between 80 and 60 mm. As the point of saturation is approached the tension of administration must be reduced to 55 mm., so as not suddenly and dangerously to overshoot the desired tension of 47 mm. On account of the relatively greater blood-supply of the central nervous system over many other parts of the body the brain will be among the first organs to be saturated and experience indicates that a general body tension of 60 mm. would be dangerous.

The narcotic action of ether is very general and affects alike all types of cells, whether plant or animal. The influences of the drug can be well studied on those cells which exhibit motor phenomena like the ciliary epithelium of the frog's throat. Motion ceases when the cells are exposed to the anesthetic vapor, and returns when the vapor is removed and the ether which has already been absorbed by the cell is eliminated. From the point of view of surgical anesthesia it is the action of the anesthetic on the central nervous system that is our chief consideration because the effects produced by the same concentration of the drug are of the type that are recognizable, and for the particular purpose of surgical proceedings especially desirable: There is first a depression of the cerebrum, then of the spinal reflex centers, and lastly of the respiratory center.

Ether has been shown by Meyer,[20],[21] Overton,[22] and others to form a "loose reversible physicochemical combination with the lipoids of the cells," thereby producing an inhibition of the cell mechanism. This cell inhibition when it concerns the cells of the central nervous system results in the complex state which we recognize as narcosis. The degree of inhibition—the depth of narcosis—is due to the percentage saturation of the cell, and this is dependent on the amount of ether present in the blood supplying the cell which, in turn, is governed by the percentage saturation or tension of the ether vapor in the inspired air.

REGULATION OF RESPIRATION

In order properly and safely to carry out general anesthesia the administrator should understand the fundamental principles of the regulation of respiration. Haldane and Priestly[14] in 1905 proved that the volume of respiration is so regulated that normally the carbon dioxid tension of the alveolar air remains constant. It has since been shown by Hasselbach and others that the carbon dioxid is not in itself

the regulator of respiration, but that it is controlled by the hydrogen ion concentration of the arterial blood. However, for practical purposes it is the increase or decrease in the carbon dioxid tension in the alveolar air that regulates the rate and depth of the respiratory movements; while variations even in wide ranges of the oxygen tension have no direct effect. "The respiratory center is so exquisitely sensitive to any rise and fall in the alveolar carbon dioxid pressure that a rise of 0.2 per cent. of the alveolar carbon dioxid pressure is sufficient to double the amount of alveolar ventilation during rest."[7] Conversely, a very slight decrease in the carbon dioxid tension in the alveolar air and respiratory center will decrease the number of respirations and even produce apnea (holding the breath).

By voluntary forced breathing for a period of one or two minutes the increased flow of air will wash out the carbon dioxid in the lungs and in the blood, thus lowering the arterial carbon dioxid tension. If now all voluntary efforts to breathe are stopped there will follow in most subjects a period of apnea lasting from thirty to sixty seconds.[4] (This little experiment should be tried by all anesthetists.) This phenomenon is particularly important in ether anesthesia, as it explains the long period of apnea that is so often seen just before the patient "goes under." During the first stage the patient breathes deeply and rapidly and is often told to do so by the anesthetist. The patient thereby washes out the carbon dioxid and reduces the normal respiratory stimulant just as he becomes sufficiently etherized to abolish all voluntary effort to breathe. The respiratory center is now entirely under the normal chemical regulatory mechanism, and since the carbon dioxid tension has been decreased by the previous forced breathing respiratory movements cease. Under these circumstances the period of apnea lasts sometimes more than one minute, and the patient may even become somewhat cyanotic before there is sufficient reaccumulation of carbon dioxid in the respiratory center again to establish breathing, for a lack of oxygen in itself is not a respiratory stimulant. Occasionally the apnea may be unduly and even dangerously prolonged, especially if the respiratory center is under the influence of a large dose of morphin (gr. $\frac{1}{4}$), given only a few minutes before etherization is started. Therefore, when morphin is used it should be given at least one-half hour before the ether is administered. Morphin reduces the sensitiveness of the respiratory center to carbon dioxid, and consequently a subject under its influence requires a higher concentration of carbon dioxid to maintain respiration; therefore, if this effect from morphin develops at the same time that there is a decrease in the amount of carbon dioxid in the respiratory center due to forced breathing, the patient may be in danger from the lack of oxygen produced by a too long apnea which lasts until a sufficient amount of carbon dioxid has reaccumulated to stimulate the respiratory center. Such an apnea causes considerable anxiety to beginners, but in itself is usually no cause for worry, provided the apnea is not confused with a cessation of respiration from obstruction of the air passages or to overetherization. It occurs only

during the first stage or just as the patient is "going under." Cessation of respiration should never occur in the second stage of anesthesia; if it does occur it would indicate either that too much ether has been given or that the air-way is obstructed.

WARMING ANESTHETIC VAPORS

A few years ago some anesthetists put considerable stress on the advantage of warming the anesthetic vapor before inhalation. The practice[5] arose from the greater ease with which patients could be etherized by a "warmed vapor" method, that is, by passing a current of air over or through warm liquid ether and administering this ether-air mixture to the patient. Technically speaking, the vapor pressure of ether at 20° C. or at room temperature is 442 mm., while at —10° C. (the temperature the liquid ether frequently becomes when rapidly vaporized) the vapor pressure is 112 mm., or one-fourth as great. If the ether bottle is immersed in warm water the ether vaporizes four times as readily—thus giving a stronger mixture, and, therefore, the patient is more quickly etherized and can be held under without difficulty.

The hypothesis has been advanced that warming the ether vapor will tend to prevent shock by avoiding an undue loss of body heat. Boothby[5] has shown by calculations of the amount of extra heat lost by the vaporizing of ether on the ordinary open mask that the amount of heat so lost is relatively small compared to the total heat eliminated by the body. Gwathmey[13] maintains, however, that a local chilling of the upper air-passages occurs. This is true to a limited extent; it is comparable to putting the patient's head out of the window and allowing him to breathe air 10 to 15 degrees lower than that of the operating room. Cool air, moreover, is more pleasant and theoretically better to breathe than warmed air. No one enjoys breathing the air which comes from a hot furnace. Undue chilling of the patient is much more efficiently prevented by directing attention to keeping the body warm and dry than to the fetish of heating the anesthetic vapor.

PHYSIOLOGIC EFFECTS OF ETHER

The physiologic effects of ether may be grouped into two stages: (1) the stage of induction and (2) the stage of surgical narcosis.

Induction.—Shortly after the commencement of the anesthetic the patient experiences a whirling dizzy sensation similar to that of alcohol intoxication with a corresponding cerebral confusion and excitation and inco-ordination in movement with restlessness. If the ether is too rapidly administered, especially if there are sudden variations in the tension of the ether vapor inhaled, there is a marked and very disagreeable choking sensation. This, however, can be eliminated almost always by a gradual and very even, though somewhat rapid, increase in the amount of ether dropped on the mask. The more rapidly this is done while still avoiding the sensation of choking, the more quickly is the blood and consequently the cells of the central nervous system saturated to the re-

quired anesthetic tension, thus shortening the stage of induction. The use of other drugs, like the oil of bitter orange peel and nitrous oxid, is unnecessary and, on the whole, inadvisable.

Ether-rausch.—During the stage of induction there is usually a period of one or two minutes in which there is a condition of analgesia with only partial loss of consciousness, from which condition the patient recovers very quickly and has little or no after-effect, such as nausea or vomiting. To intensify this stage of "ether-rausch" the patient should breathe rapidly and deeply, and the concentration of ether rapidly increased, though choking should be avoided. Such a quick induction tends to produce more mucus, and is inadvisable if complete surgical narcosis is later desired; however, the "ether-rausch" is valuable for short operations of one or two minutes' duration, like opening abscesses, felons, etc.

Surgical Narcosis.—The second stage is that of surgical anesthesia, with complete loss of consciousness and with muscular relaxation. The respiration, pulse, and blood-pressure which are increased during the stage of induction now return nearly to their normal levels and the patient should lie quietly as though asleep. There should be no respiratory stertor or material increase in mucus if the induction has been properly carried out; frequently, however, this is not the case, and the respiration is more or less audible and accompanied with a considerable increase in saliva and mucus in the air-passages. The spinal reflexes are decreased, and with deep anesthesia they are abolished; the corneal reflex, however, is one of the last to disappear, and when absent is a definite sign of a dangerously deep narcosis. The pupils should react to light and not be materially dilated. It is a very grave sign of overetherization when they are dilated and are without reaction to light. Occasionally the pupils dilate quite widely during recovery from anesthesia, but still continue to react to light; this so rarely occurs under conditions in which it is necessary to differentiate a too deep and a too light narcosis that their dilatation and rigidity should always be considered a danger sign and the ether mask immediately removed.

At no time during the course of the anesthesia should the patient become cyanosed. Cyanosis is usually due to mechanical obstruction of the air-way by the tongue or jaw falling back, accompanied by an excess of mucus. It is not necessarily due to overetherization; nevertheless, further administration of ether should cease until the cyanotic condition is relieved by obtaining a free air-way.

A perfectly conducted anesthesia is one in which from start to finish the patient breathes evenly and quietly without a material excess of mucus in the air-passages and without the slightest degree of cyanosis. The greater the skill of the anesthetist, the more frequently will he be able thus to conduct an anesthesia, and in so doing he will be mainly guided by very slight changes in the character of the respiration; the closer his attention is directed to these variations and their proper interpretation, the better the anesthesia. It is impossible, however, to describe these respiratory variations without actually demonstrating

them and their significance. The essential point is never to miss a single respiration and to note mentally any variation in their character, such as rate and depth. Practice will soon teach the significance of even slight variations. Without question, the character of the respiration is the best guide for the administration of ether, although the pulse, blood-pressure, and pupillary reflexes are valuable adjuncts, and careful record should be made of them during the course of the anesthesia.

THE CONNELL ANESTHETOMETER

For the dosimetric administration of ether the Connell anesthetometer* is very accurate. The machine delivers an ether-air mixture in which the tension or volume percentage of the ether vapor can be very accurately and easily regulated.

To produce smooth induction with the Connell apparatus the ether tension should be gradually raised during the first three minutes to 100 mm., maintained at this level from seven to ten minutes, and then during the next fifteen minutes gradually lowered to the true anesthetic tension of 47 mm. The time required for induction varies, and is dependent on the rapidity of the circulation as compared with the size of the body, because the greater the circulation rate, the more quickly will the ether be transported to the tissues and the more rapidly will the tissues be saturated to the desired tension. Although patients are found to vary in the length of time required to saturate their bodies up to 47 mm. of ether vapor, yet no measurable differences can be demonstrated in the final tension required to maintain surgical narcosis, regardless of age, sex, or condition of chronic alcoholism.

Intratracheal Insufflation Anesthesia.—The Connell[8] anesthetometer is the apparatus of choice for the administration of ether by the intratracheal method of Meltzer and Auer.[19] As the general applicability of this method is so limited the reader is referred for details to the original article of Meltzer and Auer and to a review of the subject by Cotton and Boothby.[9] It will suffice at this place to warn against the overenthusiastic and extensive use of the method except in a very limited group of cases in which obstruction of the air-way is to be feared, such as in extensive operations on the tongue and larynx, and in certain cases of acromegalia with large epiglottis. Several patients have died on the table as a result of an improper use of the intratracheal method.

Intrapharyngeal Insufflation Anesthesia.—For intrapharyngeal anesthesia the Connell anesthetometer is likewise the apparatus of choice. By means of a No. 26 F. catheter passed through the nares the ether-air mixture is conducted into the pharynx; the rate of flow of the ether-air mixture should be about 10 liters for each minute to supply a sufficient volume for each inspiration. A Crile nasal tube should be introduced through the other naris or through the mouth to the oropharynx to furnish a free escape of the excess of air and of the expired air.

*See the illustration of Connell's apparatus, pages 838, 839.

This method is particularly valuable in operations on the head, face, and neck when it is desirable to keep the anesthetist away from the field of operation. A very beautiful anesthesia can be carried out under most disadvantageous conditions by the proper use of this method.

ROUTINE ADMINISTRATION OF ETHER

Many forms of masks have been devised for the administration of ether. These are based on two different principles: one, in which there is a rebreathing of the expired air and anesthetic, is commonly known as the "closed method"; the other, in which this rebreathing of expired air and anesthetic is nearly eliminated by reducing the "dead space" of the mask to the smallest possible volume, is spoken of as the "open method."

Closed Method.—The "closed method" requires an apparatus with either a rubber bag like the Bennett[13] inhaler or a large cone with a big "dead space." With the Bennett[13] inhaler there is undoubtedly a saving in ether, not because the patient absorbs less, but because the expired ether is used again in several respirations, and, therefore, much less ether is lost into the air of the room. It is further claimed that the rebreathing of carbon dioxid will prevent "shock"; this theory was brought forth by Yandell Henderson[16] as a result of his investigations on shock and acapnia. Other physiologic investigators have given the acapnic theory of shock serious consideration, but at the present time its truth is neither proved nor disproved. Moderate rebreathing of carbon dioxid can, at all events, do no harm in itself unless pushed to an undue degree. If there is too much rebreathing, the oxygen present in the inspired air becomes so low that a slight cyanosis develops. Care should be taken, therefore, that the patient never becomes cyanotic nor the respirations become unduly deep and laborious. A distinct increase in depth and rate of respiration would indicate too much rebreathing.

Open Method.—The "open method" is, without question, the one that has given the most universal satisfaction in the majority of the American clinics and is the method used at the Mayo Clinic. No apparatus is necessary except a wire framework on which from 12 to 24 layers of gauze can be readily fitted.

1. **Preparation of the Patient.**—In preparing patients for an anesthetic they should not be allowed to have solid food for at least eight hours, and no liquids for four hours before the operation. A preliminary hypodermic of $\frac{1}{6}$ gr. of morphin given half an hour before the commencement of the anesthesia lessens somewhat the nervousness and irritability of the patient, therefore decreasing the rapidity of the respiration and pulse-rates, and, as a general rule, rendering the induction period somewhat smoother. It is not necessary, however, as a routine procedure except in gastric and thyroid cases. Morphin should never be given just before starting the etherization, as its effect will not be present in the early stages of anesthesia, but will develop more or less suddenly during the course of the anesthesia, rendering more difficult the interpretation of the variations in the character of the respiration. The

tendency of the mucous membranes to produce an excessive secretion of mucus can be lessened by the administration of atropin (gr. $\frac{1}{120}$). It is advisable to give it as a routine in operations on the thyroid.

The anesthetist should always meet the patient before he comes to the operating room. When the patient is placed on the table the anesthetist should see to it that he is comfortable and that a pad or cushion is placed under the "hollow" of his back to prevent subsequent backache. The patient should be covered with a blanket and kept warm and dry throughout the operation. The patient's hands and legs should be gently but firmly secured in a comfortable position before the anesthetic is started to prevent unpleasant experiences that sometimes occur during the stage of excitement. Care should be taken that the patient's arms do not rest on the edge of the table, as prolonged pressure on the musculospiral nerve has not infrequently resulted in a very embarrassing musculospiral paralysis of several weeks' duration. The patient's eyes should be covered with rubber tissue or wet cotton to prevent an ether conjunctivitis; this latter prevention is very essential in goiter patients with marked exophthalmos and in operations on the gasserian ganglion, for carelessness in such cases is known to have caused the loss of an eye.

2. **Induction.**—The mask is placed over the patient's face and the gauze arranged so that it passes well down on to the cheeks to prevent air from passing underneath the mask. The left hand of the anesthetist fits around the chin of the patient and the index-finger and thumb hold the mask in position. After once placing the hand in position around the patient's chin it should not be removed, and as the anesthesia deepens the pressure of the left hand is slightly increased, gently locking the jaws. This little trick is very valuable, as thereby the jaw can be held in its normal position throughout the anesthesia.

The ether is slowly and evenly dropped on the gauze mask. If this is done carefully and with skill the patient never has any choking sensation, but merely passes off through an increasingly whirling sensation of dizziness into a smooth and calm anesthetic slumber. If the patient catches or holds his breath, the rate of the dropping should be slowed and the corner of the mask lifted for one inspiration. The aim is to increase gradually and evenly, yet rapidly, the amount of liquid ether on the mask, progressively increasing the strength of the inspired mixture. After about four or five minutes the mask will be coated with frost due to the condensation and freezing of the moisture in the expired air as a result of lowering the temperature of the mask from the evaporation of the ether. A very convenient trick is for the anesthetist to place his right hand first on one side of the mask, then on the other; the warmth of the hand will increase the evaporation of the ether and strengthen the inspired ether-air mixture. Depending on the skill of the anesthetist the induction period will last from three to ten minutes, rarely fifteen minutes, when the patient will pass over into the second stage.

An "ether tremor" occasionally develops during the latter part of the first stage. This phenomenon occurs most frequently in alcoholics and in prostatic or bladder cases, and consists of a violent shaking and

rigidity of the entire body, especially marked in the lower extremities. The shaking disappears on deepening the degree of narcosis, though occasionally these patients are quite difficult to carry through into a smooth anesthesia. The cause of the tremor is not known.

Vomiting occasionally occurs during the induction period. It is always best if the patient starts vomiting to remove the mask entirely, turn his face to one side, raising the shoulder well, so that the vomitus can flow out freely. The jaw should be held open either with the fingers or with a mouth-gag if there is muscular rigidity. The mouth and pharynx should be carefully wiped out with a sponge on a Kelly clamp. Unless this is carefully done small particles of vomitus may be inhaled causing pulmonary complications. By the time the patient has finished vomiting he will usually be very nearly out of ether and semiconscious, and it will be necessary to begin the induction over again. Vomiting does no harm except to delay the period of induction and irritate the operating team; it never occurs in the second stage, although it almost always occurs as the patient is "coming out." Unskilled anesthetists occasionally allow the patient to "come out" so far during the later stages of the operation that he will vomit during the closing of the wound. It is far worse for the patient to vomit at this time than it is to hold him five minutes longer in complete narcosis.

3. **Surgical Narcosis.**—The second stage, or that of surgical anesthesia, should be characterized by quiet, regular breathing without stertor from the jaw falling back, or any marked increase in the mucus in the air-passages. There should be complete muscular relaxation. The pupils should remain contracted and react promptly to light, and the corneal reflex should be active. It is, however, a bad practice to touch the cornea with the finger, as it may cause serious postoperative irritation. In the second stage when the patient has become saturated to the anesthetic tension the constant administration of a small volume of liquid ether will be sufficient to maintain surgical anesthesia.

Unfortunately, all anesthesias do not run the ideal course. There may be considerable difficulty in holding the jaw in the proper position to allow a free and uninterrupted passage of air. If it should drop back it is brought forward by placing the finger behind the angle of the jaw and lifting it forward; the jaw can then usually be held in place by locking the teeth by a gentle pressure on the apex of the chin. In a few cases it may be necessary to force the mouth open with a wooden gag, and to hold the jaw forward, using the gag as a lever and taking great care to avoid injuring the teeth. Tongue forceps may be needed to pull the tongue forward. The anesthetist should always have a mouth-gag and tongue forceps available, but the more skilled he becomes in giving the proper dosage of ether and in maintaining a clear air-way, the less frequently will he need them. In those cases in which there is an excess of mucus it can best be cleared from the throat by a sea sponge (or gauze) on the end of a curved Kelly clamp. The Sewal mouth-gag is a very convenient instrument, as it will not only hold the jaw but also the tongue forward and leave an absolutely clear air-way.

The Crile nasal tubes are frequently a very helpful aid, especially in those patients who have more or less obstructed nares and in whom the tongue and jaw are held forward with difficulty. They are best made of soft-rubber tubing 6 inches long and $\frac{1}{4}$ inch inside diameter, cut obliquely at one end, with several holes in the side of the tube; a safety-pin is passed through the other end. These tubes covered with vaselin are passed through each naris to the oropharynx and should be introduced on the slightest obstructive difficulty.

Persons with acromegalia usually have a very large epiglottis, which may fall back when the stage of muscular relaxation has been reached and act as a flap-valve over the laryngeal orifice, thus preventing the free entrance of air into the lungs. Such a condition can immediately be relieved by the introduction of a curved Kelly clamp to hold the epiglottis forward until a tracheal insufflation tube can be introduced. It is one of the rare conditions in which the method of intratracheal insufflation is necessary to avoid tracheotomy.

Every operating theater should have a tracheotomy set sterilized and instantly available for the rare cases in which the jaw cannot be opened and the air-way cleared.

4. Period of Recovery.—The anesthetist is responsible for the immediate postoperative care of the patient, and he should accompany the patient to his room to supervise and help in the lifting of the patient from the table to the stretcher and from the stretcher to the bed.

Before leaving the operating room the patient should be thoroughly dried and his moist clothes changed. Too much stress cannot be laid on the importance of keeping the patient dry and warm not only during the operation but also during the period of ether recovery. As emphasized by Dr. Keen,[17] in his excellent Ether Day address, in proportion to the care and finesse with which these precautions are carried out will there be a decrease in the amount and degree of postoperative pulmonary complications. Cutler and Hunt[10] have pointed out that one patient in 150 to 175 dies from pulmonary complications; they lay less importance, however, on the anesthetic as the cause, but stress other factors, such as sepsis, trauma, and mobility of the parts causing pulmonary emboli.

As a rule, the patient can be placed in bed more comfortably on his side than on his back, although this will depend on the nature of the operation. As soon as the patient is conscious he should be allowed to select the position that is most comfortable for him. It will be found that the patient will naturally adopt the position which will produce the least strain and tension on the wound.

There is no contraindication against permitting a patient, as soon as he has regained full consciousness, to have small quantities of either hot or cold water as often as he wishes. If it is vomited it washes the stomach, relieving the nausea; it does not tend to produce a pernicious type of vomiting. The value of water is well recognized after an alcoholic debauch; water is of equal value—contrary to the prevailing notion—after an ether intoxication.

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CHAPTER LIX

NITROUS OXID-OXYGEN ANESTHESIA

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The field of nitrous oxid anesthesia has been constantly widening since the discovery that the addition of a proper percentage of oxygen rendered the narcosis much more free from risk and made it possible to continue the administration of the gas for prolonged operations. This discovery stimulated the investigations which have resulted in recent years in improved technic of administration, improved apparatus for controlling, measuring, and delivering the gases, and improved methods of manufacture of the gas itself. The gradual recognition of the advantages of this anesthetic agent has led to a much wider application of nitrous oxid-oxygen in general surgery and in obstetrics, as well as its continued successful employment in dentistry. During the Great War surgeons came to realize more than ever before the superior value of nitrous oxid in certain types of cases, particularly those suffering from shock or severe infection, where it was chosen deliberately in preference to ether or chloroform. As a result nitrous oxid-oxygen, though for many years slow in gaining adherents, has now come to be recognized as the anesthetic of choice in desperate cases, and with the addition of small amounts of ether for resistant subjects, or where greater relaxation is desired, it has been made adaptable to practically every type of operation.

Nitrous oxid-oxygen has several distinct advantages over other known general anesthetic agents. It is easy and pleasant to take; it rapidly produces unconsciousness; there is little danger to life when it is properly administered; it is non-irritating to the mucous membrane of the respiratory tract; acidosis is less than with other general anesthetics, and is more rapidly recovered from; there are no demonstrable deleterious effects on the liver and kidneys unless there is interference with the oxygen supply; alterations in the central nervous system are fewer and the blood changes are less marked and less enduring than with other general anesthetics, the heart and circulation are but little disturbed, variations in blood-pressure are slight unless asphyxia is allowed to occur, nausea and vomiting are absent or of short duration in the vast majority of cases, and the gas is promptly and completely eliminated, leaving no serious or lasting after-effects. The resistance of the patient, therefore, is not appreciably lowered, and he begins his fight for recovery with full consciousness almost immediately after operation with heart, lungs, and kidneys unimpaired, so that his vitality is not wasted in fighting the after-effects of the anesthetic. How important a factor this

is in the problem of recovery from operative shock is realized when we consider that the majority of postoperative deaths have been due largely to the after-effects of anesthesia.

The difficulty of properly administering nitrous oxid-oxygen confines the use of this anesthetic to the experienced administrator, who should have a thorough knowledge of its action as well as an appreciation of its limitations, and should possess unerring judgment in the management of patients of unusual type or in unusual conditions. In the majority of cases nitrous oxid-oxygen produces a light anesthesia unless a dangerous degree of asphyxia is allowed to occur; consequently, there is some difficulty in obtaining perfect relaxation and freedom from reflex movements, and any unexpected manipulation on the part of the surgeon may present difficulties which the untrained anesthetist would not know how to meet. That the deep reflexes are never abolished and that muscular relaxation does not become complete is, however, an element of safety, as it is well known that profound anesthesia with deep muscular relaxation is decidedly injurious to the patient through a loss of muscle tone, and because of the increased amount of acidosis which occurs. Sufficient muscular relaxation, however, can be obtained by the use of alkaloidal narcosis, local anesthesia, and by supplemental etherization when required by resistant subjects. Certain individuals are especially resistant to the gas, consequently are difficult to manage. They are the patients who would require a large amount of any general anesthetic, those possessing a strong, vigorous constitution; those who are of an extremely nervous temperament; fat subjects, and those addicted to drug habits or the excessive use of alcohol and tobacco. But the ever-increasing number of skilled administrators and the introduction of the newer types of apparatus are gradually overcoming the disadvantages which have so much retarded the development of this anesthetic.

Nitrous oxid-oxygen is indicated in all minor operations and cases of short duration. It is of special value and should always be used in serious surgical risks, where the odds are against recovery, as in acute infections, anemias, shock from any cause, respiratory affections, impaired kidneys, diabetes mellitus, grave peritonitis, weak and cachectic patients, amputation, and cesarean section. In obstetrics, analgesia with nitrous oxid-oxygen has a large field of usefulness, as it is efficient for the relief of pain in the great majority of patients, and, according to Davis,[1] Ryder,[2] and other observers, when properly administered can be continued over a period of several hours with little danger to either mother or child.

There are no real contraindications to the use of nitrous oxid-oxygen if properly administered. In certain conditions the risk is very much increased, as in cases of respiratory obstruction due to enlarged tonsils, cellulitis, tumor of the neck, or any swelling which will be made worse through venous congestion; bad heart lesions with broken compensation, or hypertrophied heart, where there is very high blood-pressure with pronounced arteriosclerosis. These conditions may all

be met by the administration of a suitable percentage of oxygen, avoidance of struggling and excitement, and care in maintaining as free an air-way as possible. It is commonly believed that nitrous oxid-oxygen is contraindicated by high blood-pressure, militating against the use of this anesthetic in the aged because of their intolerance of asphyxia and circulatory stress. Jones,[3] with an experience of 13,000 administrations of nitrous oxid-oxygen, found by experiments during operations in brain surgery that "discoloration, dilatation, and protrusion of the

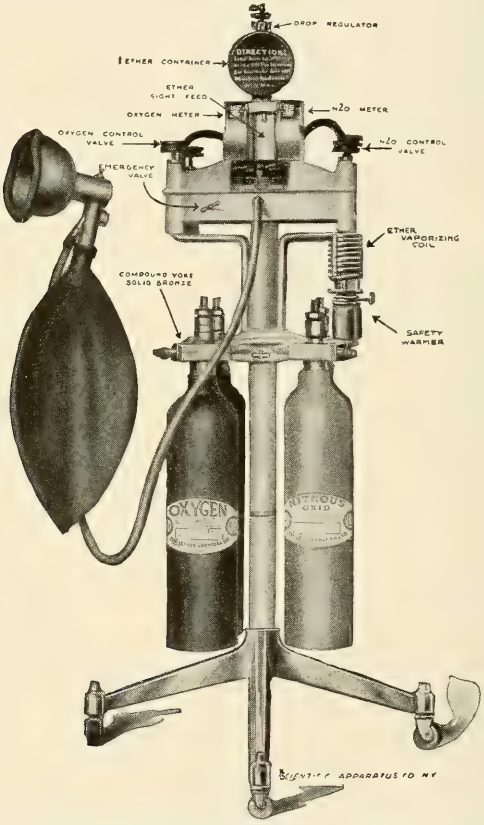

Fig. 634.—Connell Nitrous Oxid-oxygen Apparatus. Hospital Model. (Courtesy of Dr. Karl Connell.)

brain occurred only in the presence of oxygen deprivation and assumed dangerous proportions only when asphyxia was imminent." McKesson's[4] careful observations over a period of twelve years have firmly convinced him that nitrous oxid-oxygen does not increase the blood-pressure and is not contraindicated in any case of arteriosclerosis. On the other hand, Cannon[5] found that in shocked animals a fall of pressure similar to that observed with ether occurs with strong concentrations of nitrous oxid, but no drop occurs with nitrous oxid used in a strength just sufficient to produce anesthesia. Children under five

years with the air-way blocked by enlarged tonsils and adenoids present a real danger. Children are easily asphyxiated and pass quickly from light to deep anesthesia, so with an air-way that is blocked it is not easy to maintain a satisfactory narcosis and resuscitation is very difficult.

To produce and maintain a safe and satisfactory anesthesia with nitrous oxid-oxygen requires a most accurate mechanical control, with a definite, even, and continuous flow of the gases. There are several excellent apparatus of the continuous-flow type in use at the present time, among which should be mentioned the McKesson, Boothby,

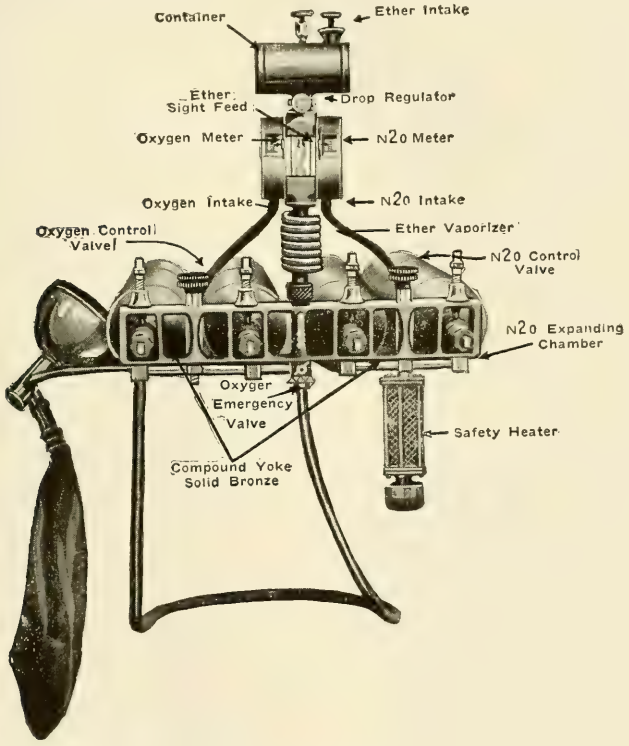

FIG. 635.—CONNELL NITROUS OXID-OXYGEN APPARATUS. PORTABLE MODEL. (Courtesy of Dr. Karl Connell.)

Ohio Monovalve, Gwathmey, and the Walter-Ewen. The improved apparatus of Connell[11] is a distinct advance over all others in the development of this type of machine.

Its special features are the meters which accurately measure the gases, enabling one to know at all times and at a glance the exact quantity being delivered; the control valves replacing the old-style reducing valves and allowing an even, constant flow; an ether attachment by which ether may be fed by the drop through a sight feed into the flowing gases; a safety lamp for the nitrous oxid control valves to prevent the expanding gas from freezing in the valves, and to insure vaporization

of the ether; a safety-valve which provides for immediate delivery of oxygen directly to the face-piece in case of emergency; an air-tight face mask provided with an exhaling valve which can be so adjusted as to allow as much rebreathing as is required by the patient.

The technic consists in applying the mask with the rebreathing bag filled with nitrous oxid which is set flowing from the apparatus at the rate of 6 liters per minute. For the average individual this rate of flow can be maintained with but slight variations throughout the entire operation. Occasionally, for large robust subjects 8 liters per minute will be required. Rebreathing is allowed from the start, but is so regulated that the greater portion of each of the first four or five exhalations is expelled. The oxygen is then allowed to flow at the rate of $\frac{1}{2}$ liter per minute, care being taken to avoid cyanosis, and is gradually increased, depending upon the color and the required depth of anesthesia, until the proportion of gases suited to the patient is determined. During the first ten or fifteen minutes the average individual requires at least 8 per cent. of oxygen, or a delivery of 0.6 liter of oxygen per minute in a volume of 6 liters of nitrous oxid, after which the oxygen may be increased to approximately 12 per cent., or a delivery of 0.8 to 1 liter per minute in 6 liters of nitrous oxid. After the meter is adjusted for the proper proportion of gases delivery will be constant and uninterrupted. Should there be any change in the clinical reaction, the dosage can be instantly regulated and the flow of gases can be increased or decreased according to the tidal volume requirements.

The induction should not be hurried and the anesthetist should not allow the operator to begin until the patient is ready, as it may cause tremor, rapid pulse, and respiration. Ordinarily from five to eight minutes should be allowed before sufficient saturation with nitrous oxid is obtained. When anesthesia is established it will be indicated by full regular respirations of moderately increased rate with a slight inspiratory roughening, partial relaxation, and absence of the corneal reflex. In a rapidly produced nitrous oxid-oxygen anesthesia any element of asphyxia not only increases the difficulty of producing a smooth narcosis but also increases the danger to the patient. Struggling during induction should be avoided, as it may be detrimental to the heart. Jackson[6] has called attention to the danger of cardiac slowing, especially characteristic of excited and struggling subjects, if the administrator attempts to crowd the gas. In his experiments on dogs he found that this slowing of the heart was often very marked and he believes that it may be the cause of death in some cases.

If cyanosis develops it should be remedied by an increased percentage of oxygen or by relieving any obstruction in the air-passages. Undoubtedly many of the deaths under nitrous oxid-oxygen have been due to the erroneous idea that a certain amount of cyanosis is necessary and safe. Even slight cyanosis, if prolonged, will result in increased acidosis, with postoperative nausea, vomiting, and acetonuria. Resistant subjects often show cyanosis before anesthesia is well established, and there should be no hesitancy in these subjects in giving

enough ether to establish a proper control. When ether is added to the mixture of gases the percentage of oxygen should always be slightly increased. Certain subjects require a higher percentage of oxgyen than the average individual, as anemias and toxic conditions in which the oxygen supply to the tissues is impaired because of the diminished oxygen-carrying capacity of the blood; patients in whom the respiratory volume is small due to a diseased condition of the lungs or mechanical obstruction to the air-passages; children, in whom the respiratory exchange is less efficient, due largely to the small size of the respiratory passages; patients with cardiorenal changes, cases of shock, cachexia, starvation, or any condition where there is an excess of acid products due to a disturbed metabolism. Such patients often require as high as 20 per cent. of oxygen in order to maintain a proper oxygenation of the tissues.

Interference with free respiration increases the strain on the cardiovascular system to a dangerous degree and tends to exhaust the patient. An air-way tube should be inserted when any nasal or tongue obstruction is present.

Fig. 636.—Connell Air-way Tube. (Courtesy of Dr. Karl Connell.)

Although the color of the patient can usually be relied upon for regulating the amount of oxygen required by the individual, the anesthetist should not depend upon this sign alone in order to determine the actual depth of anesthesia. The color may be misleading, as anemic and septic patients usually show little change in color until they are deeply under the influence of the anesthetic, and, on the other hand, full-blooded individuals often show cyanosis early, even before they are anesthetized. The only safe and satisfactory guide in determining the actual depth of the anesthesia is the preponderance of available signs, including the color, the respirations, the eye reflexes, the general muscular manifestations, and the pulse.

The anesthetist should endeavor to *keep the patient pink, avoiding, if possible, even the faintest cyanosis.* A green color appearing at any time indicates approaching nausea, and an ashy pallor denotes danger to the circulation due to loss of vasomotor tonicity or impairment of the heart's action. The respirations should be full, regular, and moderately increased in rate. Much exaggerated breathing indicates too

light a grade of anesthesia or an accumulation of carbon dioxid from excessive rebreathing. Slow, irregular, spasmodic respirations indicate too much nitrous oxid or a dangerous degree of asphyxia. On the other hand, slow, superficial but regular respirations often occur with too much oxygen. The phonation heard in light anesthesia is purely reflex, while that heard in profound anesthesia is due to muscle spasm of the vocal cords. The eye reflexes may be obscured by the preliminary morphin. With a properly balanced mixture of gases the pupils are small or medium, and react sluggishly, or not at all, to light. The eyeballs are fixed or slowly roll from side to side and the conjunctiva is insensitive. The dilated pupils, due to reflexes or pain, often seen when a patient is lightly anesthetized, may be confused with the widely dilated pupils of profound anesthesia. The latter do not react and are often irregular in shape. The muscular rigidity of light anesthesia must not be confused with the rigidity which occurs in asphyxia. The former calls for an increase in nitrous oxid in order to deepen the narcosis, but when the rigidity is due to asphyxial spasm, which will be revealed by cyanosis of the lips, nails, and lobes of the ears, any increase in nitrous oxid serves only to decrease the oxygenation, as relaxation cannot be secured by deepening the asphyxia. The percentage of oxygen must first be increased for a few breaths, though not enough to produce a pink color, as the patient may come out from under the influence of the anesthetic. Clonic movements, twitchings, and wide-spread muscular contractions result from too much nitrous oxid or from obstruction to the air-passages, and they should be remedied by immediately increasing the oxygen, decreasing the nitrous oxid, and by relieving any obstruction which is present. The pulse is usually moderately increased in rate, although there may be no change from the rate as determined before operation. A rapid pulse of good quality occurring in light anesthesia is due to reflexes or pain, while a rapid pulse of weakened quality indicates hemorrhage or approaching collapse from failure of the circulatory mechanism. A slow, irregular pulse, showing the tension temporarily increased, then falling rapidly, indicates imminent asphyxia or overdosage with nitrous oxid. Similarly, a slow pulse may be due to overdosage with carbon dioxid following excessive rebreathing.

Prolonged nitrous oxid-oxygen administration without rebreathing is almost certain to leave the patient in an exhausted state and may be a contributory factor toward shock. Rebreathing in most cases is decidedly beneficial, as it deepens the anesthesia and stimulates the respiration, thereby controlling the tendency of the preliminary alkaloidal narcosis to decrease the rate and volume of pulmonary ventilation. It also limits the expense of nitrous oxid-oxygen anesthesia. The amount should vary but little, and should be governed by the symptoms in each case. Such rebreathing as will diminish the oxygen in the respired air should be scrupulously avoided, as it may cause severe postoperative headache and vomiting. The undesirable effects which follow the prolonged administration of nitrous oxid-oxygen result largely from too much rebreathing with an insufficient amount of oxygen present.

If rebreathing is excessive the patient will begin to show symptoms of light anesthesia, followed by asphyxial manifestations with rapid forced respiratory efforts, rapid pulse, a livid appearance, and a cold, clammy skin. The condition should be relieved by oxygen or by increasing the total gas flow, otherwise respirations gradually cease due to overdosage with carbon dioxid. Gatch[7] has reported 2 cases where the papatients had been rebreathing a long time, when the pulse suddenly showed slowing with increased tension. He attributed the slow pulse to a sudden stimulation of the cardio-inhibitory center by an excess of carbon dioxid in the blood, and found that washing out the lungs with a fresh supply of gases caused the pulse-rate to rise immediately. Other administrators have observed the same slowing of the pulse with excessive rebreathing.

Positive pressure is sometimes a useful procedure in managing difficult cases. It produces a more profound narcosis and is easily accomplished by keeping the rebreathing bag slightly distended. It should not, however, be continued over long periods, as it may be attended with some danger because of the increased respiratory exertion and the hindrance to the pulmonary circulation embarrassing the action of the heart.

Satisfactory results with nitrous oxid-oxygen cannot be obtained without the use of preliminary alkaloidal narcosis by morphin or other narcotic. Except in case of infants, the aged, or those whose reflexes are already sufficiently dulled morphin (gr. $\frac{1}{4}$ to $\frac{1}{8}$) with atropin (gr. $\frac{1}{100}$ to $\frac{1}{150}$) should be routinely employed about one hour before operation unless specifically contraindicated either by the patient's condition, an idiosyncrasy to morphin, or unless acidosis is already present. With the aid of these adjuvants the course of the anesthesia is rendered much smoother, the necessity for the addition of ether is less frequent, the percentage of oxygen can be augmented, and excessive secretion of mucus is avoided whenever the addition of ether is found necessary. The small amount of ether ordinarily required during a nitrous oxid-oxygen anesthesia has no effect on a rapid and agreeable recovery. For resistant subjects in whom no narcotic effect is made manifest at the time of operation, it is safer and more satisfactory to supplement with ether than to increase the dose of morphin and atropin. Scopolamin (gr. $\frac{1}{100}$) may be used in place of atropin, but occasionally it depresses the circulatory mechanism to a dangerous degree.

Close co-operation on the part of the surgeon and the anesthetist is most essential for the best results with nitrous oxid-oxygen anesthesia. The surgeon should accustom himself to working rapidly and with the gentlest manipulation so as to produce the least possible trauma. The anesthetist should use the least amount of anesthetic possible, varying the depth of the narcosis to meet the requirements of the different phases of the operation.

In nose and throat surgery it is often difficult to produce an even and satisfactory narcosis, due to irregular breathing, interference with free respiration by blood and mucus, and because of air dilution by

mouth breathing. Analgesia by the nasal administration of nitrous oxid-oxygen is rapidly gaining adherents for operations of this type. Analgesia means the loss of the sensation of pain without the loss of the sense of touch or of general consciousness. The patient still retains his mental faculties, although their activity is somewhat dulled. He is able to answer questions, though sluggishly. If he fails to respond, anesthesia is supervening, and, on the other hand, any sign of suffering means that analgesia has not become complete. Co-operation on the part of the patient is most essential, as it is difficult to obtain satisfactory results with patients who do not want to be conscious of what is going on. Induction is rapid, requiring from one to two minutes, starting with equal parts of nitrous oxid and oxygen and gradually reducing the proportion of oxygen until the proper balance of gases is found. The proportion of oxygen required may vary between 50 and 10 per cent., depending upon the type of patient and the amount of rebreathing which is allowed. If the ratio of gases suited to the patient is carefully maintained, analgesia may be prolonged for several hours, yet in five or six breaths of a richer mixture of nitrous oxid analgesia may be deepened into anesthesia. In oral surgery it is often necessary to switch from rebreathing to a free flow of the gases delivered under pressure in order to prevent mouth-breathing, and this method is very wasteful. The addition of ether is frequently required and is usually more satisfactory in the management of difficult operations of this type.

Death under nitrous oxid-oxygen anesthesia usually results from asphyxia or from overdosage. The safety element in this form of anesthesia is oxygen. Few deaths have occurred where the color of the patient remained pink, although several deaths are reported to have occurred suddenly, almost without warning, and efforts at resuscitation were unavailing. The warning sign of the onset of asphyxia is cyanosis accompanied by forced respirations which rapidly become slow and dyspneic in type, then convulsive, as the process of deoxygenation continues, until exhaustion supervenes, with muscular flaccidity, dilated pupils, slow, irregular heart action, and finally breathing ceases after a few prolonged sighing respiratory efforts. Asphyxia calls for the usual methods of respiratory resuscitation, but should always be avoided by increasing the oxygen when cyanosis appears. Overdosage with nitrous oxid is manifested by a livid appearance, wide-spread muscular contractions, labored respirations, dilated pupils, absence of reflexes, and a slow, irregular pulse. If the condition is not immediately relieved by oxygen or air, together with artificial respiration, the color becomes a bluish gray, the jaw and thoracic muscles become fixed in tonic spasm, the heart dilates, and death rapidly ensues. Gatch[8] is of the opinion that "with nitrous oxid in the absence of asphyxia overdosage is impossible." Cotton and Boothby[9], on the other hand, state that "some cases even when respiring a mixture of gas and oxygen in which the proportion of the latter is sufficient to maintain the patient pink, might even be brought under too profound an influence of nitrous oxid

and the anesthesia be made dangerously deep." They claim to have demonstrated that such a condition frequently occurs, calling attention to the fact that it is often necessary toward the end of a long operation to use equal parts of oxygen and nitrous oxid. The signs of overdosage observed by them when sufficient oxygen is being delivered so that the color of the patient is maintained pink are stertorous respirations and the onset of an excessive secretion of mucus followed by a death-like pallor, loss of facial reflexes, shallow respirations, probably a fall of blood-pressure, and death from respiratory paralysis. The treatment is oxygen and artificial respiration.

If vomiting occurs during the course of nitrous oxid-oxygen anesthesia, the danger of aspiration should be avoided by allowing the patient to come out and empty his stomach with the least possible effort, and the anesthetist should wait until the reflex has subsided before continuing the anesthesia.

Statistics in so far as they can be relied upon show a lower mortality rate with nitrous oxid-oxygen than with any other general anesthetic. In 1917 Crile[10] reported over 15,000 cases without a single death. Undoubtedly a certain number of unreported deaths occur under this form of anesthesia due to its more frequent use in cases where little hope of recovery is offered, but where death cannot properly be blamed on the anesthetic. The use of nitrous oxid-oxygen in these cases many times means the saving of lives. During the Great War nitrous oxid-oxygen was extensively used at many of the British and American hospitals in France, and the clinical results obtained prove conclusively its superior value, especially in desperate cases, over all other general anesthetics. It was adopted by the Interallied Surgical Congress as the anesthetic of choice, and its use in conjunction with local anesthesia was especially recommended for abdominal cases and for *all patients suffering from shock.*

In the British base hospitals where nitrous oxid-oxygen was used the death-rate was approximately one-half of the rate in the other hospitals. Marshall, Chief of the Anesthetic Service of the British Army, reported that the lives of many patients in severe shock where amputation was necessary were saved by nitrous oxid-oxygen anesthesia, and it was his conviction that no other anesthetic should be used for that type of case. He found that such patients died when chloroform was used, and that although they improved on the table with ether, they frequently died one or two hours later. When nitrous oxid-oxygen was used there was no evidence of shock from the operation, blood-pressure rarely fell as much as 15 mm., and the pulse-rate did not rise more than 10 beats per minute. The patients were fully conscious in five minutes and there was no collapse in the next few hours. Excellent results were also obtained in septic cases, and his best results were in abdominal operations where the use of nitrous oxid-oxygen supplemented by local anesthesia reduced the mortality rate from 50 per cent. with ether to 29 per cent. That was the best record of the war, according to the opinion of Crile, who in 1915, at the American Ambulance at Neuilly,

demonstrated to the British surgeons the technic of nitrous oxid-oxygen anesthesia with which they obtained such satisfactory results.

Reports from the American hospitals using nitrous oxid-oxygen showed a lowered mortality resulting from the fact that there was no added shock to patients who were already suffering from shock; less toxemia, with an absence of postoperative nausea and vomiting in the great majority of cases, which permitted the patients to be fed directly after the operation, resulting in an almost immediate improvement of their general condition; less postoperative respiratory complications; and much saving of time, as the quick induction speeded up the operative work and the rapid return to consciousness permitted many of the patients to care for themselves, thus relieving for other work those who would have been detailed to watch their recovery. In Paris, at the American Red Cross Hospital under the command of Blake, nitrous oxid-oxygen occasionally supplemented by ether was used in approximately 99 per cent. of all operations, with generally satisfactory results.

Experience has shown, therefore, that nitrous oxid-oxygen not only possesses most of the advantages of the hydrocarbon anesthetics, but is free from their characteristic dangers, as it is a non-irritative, non-lipoid solvent, non-injurious to the liver and kidney cells, only slightly toxic, and rapidly and completely eliminated. The literature is almost universally favorable to this form of anesthesia, and the fact that it has become the anesthetic of choice in many cases formerly considered impossible risks proves conclusively its value as compared with other general anesthetic agents. The recent improvements in the apparatus, the increasing number of skilled administrators, and the growing appreciation by surgeons of the value of nitrous oxid-oxygen indicates that the future will find it much more generally employed.

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CHAPTER LX

LOCAL ANESTHESIA*

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Not only has local anesthesia gained much in favor during the past few years, but its field of usefulness has greatly increased. This is due largely to the discovery of substances which possess great local anesthetic properties, and which, at the same time, are free from the high toxicity of cocain. When synthetic cocain was discovered so that the supply and price made this drug generally available, it was used very extensively for producing local anesthesia, but so many deaths occurred from its use, owing to its very high toxicity and the great susceptibility of many individuals to its effects, that local anesthesia in general surgery received quite a set-back, not, however, before the advantages of local anesthesia itself had become established.

The desire to find some substance which would produce local anesthesia, yet be free from the toxic properties of cocain, greatly stimulated the activity of synthetic chemists, and as a result of their labors many new substances were discovered. Among these may be mentioned alypin, anesthesin, apothesin, benzyl alcohol, chlorbutanol (chloretone), cycloform, eucain-a, eucain-b, holocain, nirvanin, novocain (procain), orthoform, quinin urea hydrochlorid, stovain, and tropacocain.

The ideal local anesthetic should possess the following properties: 1, Marked local anesthetic properties; 2, solubility in water; 3, relative non-toxicity; 4, be readily sterilizable; and 5, non-irritating to the tissues. When measured by this standard most of the above-mentioned substances are found wanting in one or more of these particulars. Stovain is irritating to the tissues, and according to Laewen[1] a 4 or 5 per cent. solution applied to a nerve trunk may cause irreparable injury to the nerve. Gangrene of the skin has been produced by the use of a 2 per cent. solution. All quinin salts in solution, when injected subcutaneously, produce local anesthesia. As quinin and urea hydrochlorid is the most soluble of quinin salts, it is the one most commonly used for this purpose. While the anesthesia produced by quinin and urea hydroclorid is slow in its onset, it persists much longer than that produced by any other known substance. Unfavorable results, however, were soon noticed. It was found that the injection of a solution stronger than 0.25 per cent. caused an induration of the tissues. With solutions of from 1 to 3 per cent. the swollen area assumes at times a mottled ecchymotic appearance, and necrosis or sloughing of the tissues may

* Supplementary to Chapter LXXXI, Vol. V, p. 1045.

occur. Hertzler[2] has shown that this swelling and induration are due to a pure fibrinous exudate.

The remaining two of these substances, novocain and apothesin, when judged by the five points above mentioned head the list of known anesthetics today. Novocain is described in Vol. V, page 1054. It is now manufactured in this country under the name of procain, which term will be used hereafter. Apothesin is a comparatively recent American discovery and is a strong rival of procain. It is readily soluble in water, its solution can be sterilized by boiling, it is relatively non-toxic and non-irritating to the tissues, and possesses very strong anesthetic properties. With apothesin the anesthesia is possibly a little slower in its onset than it is with procain, but it is as complete and the duration as long. While procain and apothesin are described as relatively non-toxic, it should be distinctly understood that all known local anesthetics are protoplasmic poisons with an affinity, more or less marked, for nerve-cells. The term "non-toxic," therefore, is purely relative, and refers to the degree of toxicity when compared with that of cocain, which drug is used as a basis of comparison for the reason that it is the most highly toxic of this class of agents. It is a self-evident fact that any substance which has the property of suspending the activity of nerve-cells, either temporarily or permanently, will cause death if brought in contact with nerve centers in sufficient amount. A definite lethal dose of any of these substances cannot be given, for the reason that there are a number of factors which greatly modify the effects, chief among which are the concentration of the solution and the rapidity of introduction. The quickest way of bringing a drug in contact with the nerve centers, aside from direct application, is to inject it directly into the blood-stream. When injected directly into the circulation the amount necessary to produce death varies with the strength of the solution and the rapidity of injection. An amount which would cause almost instant death if injected quickly may be given slowly without causing any serious symptoms, and several times the amount that will cause serious symptoms in a concentrated solution may be given with safety if in a very weak solution, and an amount which will cause symptoms when injected into the circulation may be given subcutaneously without danger, due to the fact that in the latter case it is absorbed more slowly. These facts are all of great importance from a practical standpoint, and from them may be deduced the principle that it is not alone the amount of the drug that is dangerous, but the amount that reaches the nerve centers in a given time. As the rate of absorption is a material factor in the causation of symptoms, anything which will delay or retard absorption increases the amount which may be given with safety. It has been found that the addition of some preparation of epinephrin to the solution greatly delays the absorption by its contractile effect on the blood-vessels. This subserves two purposes: It permits the use of a much larger quantity of the drug without danger, and it intensifies and prolongs an anesthesia by retaining the solution in contact with the nerves for a much longer time. As cocain is so highly toxic and so many

individuals are particularly susceptible to it, and as we now have other substances possessing high anesthetic properties combined with low toxicity, we believe that cocain should not be used for local anesthetic purposes in general surgery, although it is a valuable drug and has a distinct field of usefulness in the surgery of the eye and other specialties. Procain and apothesin are the local anesthetics of choice today, but, notwithstanding the fact that they are only about one-eighth or one-tenth as toxic as cocain, it should not be forgotten that the principles above laid down apply to them as well, and that death may be caused by the injection of a solution of either of them directly into the circulation.

Preparation of the Solution.—It is very important that the solution should be properly prepared. Thorough sterilization is essential to prevent infection, with occasional sloughing. Ordinary tap-water frequently contains anaërobic spore-forming organisms which are difficult to kill. Such water is not easy to sterilize, and its use after a single boiling may be followed by infection and sloughing. It is better, therefore, to use distilled water which has been sterilized in an autoclave, or by fractional boiling. Solutions of procain and apothesin may be sterilized by boiling, but prolonged boiling diminishes their anesthetic property; hence it is advisable to sterilize the water before the addition of the drug, and, after the desired amount has been added, to reboil for about three or four minutes. Sterile physiologic salt solution, or Ringer's fluid, may be used instead of distilled water if desired, but they possess no special advantage. All local anesthetics are complex substances which are easily decomposed; hence nothing should be added to the solution which is incompatible. Some substances may be added to the solution when it is cold which would undergo decomposition at the boiling temperature. Hence, if two or more substances are to be combined for any purpose each should be sterilized separately and mixed later as desired. I add chlorbutanol to the extent of saturation to the solution after it has been sterilized, but it should not be added until the solution cools, as it will not stand the boiling temperature without decomposition. Chlorbutanol is soluble in water only to the extent of 8 parts per 1000, but any excess added is harmless, as the crystals simply settle at the bottom. Chlorbutanol not only intensifies the anesthesia, but it is also a mild germicide and thus insures the sterility of the solution if it is to be kept any length of time before using. Fresh solutions, however, should always be used when possible. The addition to the solution of some preparation of epinephrin for the purpose of delaying absorption and thus prolonging and intensifying the anesthesia has already been mentioned. The duration of the anesthesia produced by procain or apothesin without the addition of epinephrin is only from five to twenty minutes, depending upon the strength of the solution used, a time altogether too short for the performance of extensive operations. It is essential, therefore, that epinephrin be added if a prolonged anesthesia is desired, and as the substance is very unstable and will not withstand boiling it should

never be added until the solution is ready to be used. About 2 or 3 drops of a 1 : 1000 solution may be added for each 30 mils* of the anesthetic solution. There are other substances which, added to the solution, intensify and prolong the anesthesia. I add calcium chlorid for this purpose with excellent results. Hoffmann and Kochmann[3] recommend potassium sulphate for this purpose. They claim that the addition of 0.25 per cent. of potassium sulphate to a 0.25 per cent. solution of procain will produce an anesthesia equal to that of a 0.5 per cent. solution of procain without the potassium sulphate. Separate 2 per cent. solutions of calcium chlorid and potassium sulphate are made and sterilized. By having separate solutions one or both may be added as desired. For ordinary work I take 3 parts of a 1 per cent. solution of procain or apothesin and 1 part each of the 2 per cent. solution of calcium chlorid and potassium sulphate, to which is added the epinephrin just before using. This makes a little more than a 0.5 per cent. solution of the anesthetic, which injected subcutaneously will produce an anesthesia lasting two hours or more. The duration of the anesthesia may be lengthened by increasing the calcium chlorid content or the strength of the solution. It is difficult to state the maximum amount of this solution which can be used with safety. Age and physical condition of the patient and the location of the injection have to be taken into consideration. I have used as much as 200 mils in adults and have never seen any serious symptoms of intoxication. When it is desired to block large nerve trunks with a small amount of the fluid the strength of the original anesthetic solution may be increased to $1\frac{1}{2}$ or 2 per cent. It should be remembered that the danger of intoxication increases with the strength of the solution used.

The only instruments necessary for making the injection are an ordinary hypodermic syringe with some fine sharp needles and a 10- or 20-mil glass Luer or Record syringe, with several needles from 5 to 12 cm. in length to fit. A small wheal is made in the skin with the hypodermic and a fine needle, through which is introduced one of the large needles selected for the particular purpose, the end of the needle being carried to the point where it is desired to deposit the fluid. In blocking large nerve trunks the needle, in places, must penetrate to a considerable depth, and must invade regions rich in large blood-vessels. The danger connected with the injection of any of these substances directly into the circulation has already been set forth. It is evident, therefore, that every precaution should be taken against the point of the needle being in a blood-vessel at the time of the injection. To guard against this accident the needle should always be introduced detached from the syringe. Should the needle penetrate a blood-vessel the fact will at once become known by the escape of blood from the needle. The method of injecting while the needle is being introduced, in the hope that the fluid as it escapes from the needle will displace the blood-vessel and thus prevent its penetration, is not as safe as the introduction

* This word *mil* is the most recently adopted term to indicate 1 c.c., *i. e.*, the millionth part of a cubic meter.

of the detached needle. I know of one sudden death which occurred while the surgeon was injecting a solution of novocain without observing the simple rule of introducing the needle detached from the syringe. The solution evidently was injected directly into the circulation.

If the infiltration method is to be used the fluid should be slowly disseminated throughout the tissues involved in the operation; the skin itself, however, need not be infiltrated, as the fluid in the subcutaneous tissues just beneath it anesthetizes it by diffusion. In nerve blocking the fluid should be deposited in direct contact with the nerve trunk, but it is not necessary or desirable to penetrate the nerve itself with the needle. One must have an accurate knowledge of the location of nerve trunks, their relation to surrounding parts, and the best way to reach them, in order to block successfully. A failure to secure a good anes-

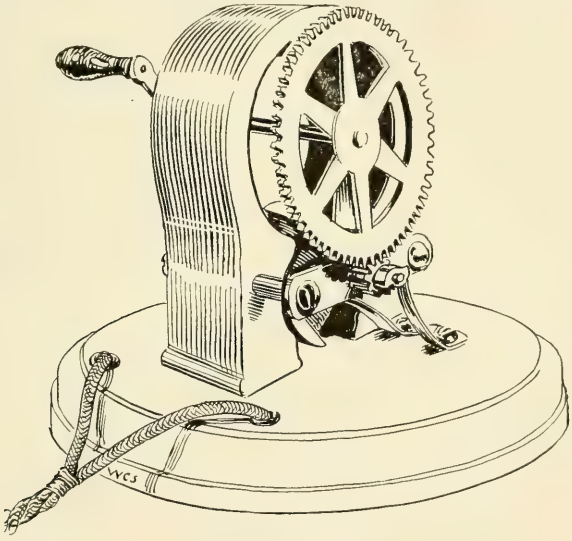

Fig. 637.—Tesla Dynamo.

thesia always means that the fluid has not been brought properly in contact with the nerve at the right point. When introducing the needle one must learn by practice to judge accurately, and to keep in the mind's eye the location of the point. To facilitate the finding of mixed nerves, such as the sciatic, that lie deeply, I use a small toy Tesla dynamo and a long hollow needle insulated to within 2 or 3 mm. of the point (Fig. 637). A small copper electrode wrapped in wet absorbent cotton and connected with the negative pole is placed on the calf of the leg or any other indifferent part of the body. The positive wire ends in a small coupler that fits the socket end of the insulated needle. As the needle is introduced in the direction of the nerve an assistant slowly turns the crank of the dynamo. A slight electric discharge occurs with each "click" of the instrument, and when the non-insulated point of the needle comes in contact with the nerve a contraction of the muscles supplied

by the nerve takes place. The crank of the dynamo should be turned very slowly so as to produce one "click" at a time. As soon as the point of the needle is demonstrated to be in contact with the nerve, the wire is detached and the solution injected directly on the nerve. By use of this simple and inexpensive device almost any nerve may be easily located.

Preparation of the Patient.—No special preparation of the patient is necessary. The fear of pain, which is the foundation of the feeling of horror which some people experience at the idea of an operation, is rapidly disappearing as the advantages of local anesthesia become better known. It is quite common now for patients to request that the operation be done by the local method. The necessity, therefore, of administering morphin or morphin and scopolamin in order to narcotize the patient before the operation, to diminish or prevent so-called psychic shock, does not exist. The confidence of nervous patients should be secured and their apprehensions of being hurt allayed. They should not be surprised by being stuck with the needle when not expecting it, but should be informed when the needle is to be introduced. They should also be informed when the anesthesia comes on that they will experience a sensation of numbness or weight in the region blocked, and that gross movements of the parts may be felt, but that none of these sensations will be painful. When patients know what to expect they are not apprehensive, and if properly handled it will rarely be necessary to give a patient morphin to allay nervous fear. If the operation is to be a prolonged one, it may be advisable to give a small hypodermic of morphin to relieve somewhat the irksomeness of lying still in one position so long.

After-effects.—There are really no after-effects directly attributable to local anesthesia. Naturally, after the effects of the anesthetic have worn off the wound will be sensitive and tender and there will be more or less of a burning sensation, the same as there would be had the wound been produced while the patient was under a general anesthetic, but there is no after-pain due to the solution itself. If considerable of the drug has been used, regardless of the character of the operation or the location of the injection, about 5 per cent. of the patients will have a little nausea, and some of them will vomit slightly, usually about an hour or so after the operation is over. The vomiting, however, is never severe, such as is so common after ether anesthesia, and the nausea is of short duration. As a rule, patients are able to partake of nourishment and drink on returning to their rooms from an operation, and may be permitted to do so should there be no contraindication. If morphin or scopolamin be given preliminary to the operation, about 30 per cent. of the patients will have nausea and vomiting, usually, however, of a mild type. For this reason the preliminary use of morphin is objectionable and should be omitted except in special cases. Gas-pains after abdominal operations are due largely to a certain amount of traumatism incident to exposure and handling of the intestines and peritoneum, consequently they are not entirely absent following operations done

under local anesthesia, although they are less frequent and severe than after ether anesthesia.

Advantages and Disadvantages.—Local anesthesia is much safer to the patient than general anesthesia, and for that reason should be preferred in suitable cases. Since the use of cocain has been discontinued as a local anesthetic in general surgical work deaths under local anesthesia have been very few indeed, and have occurred when strong solutions were used or when the solution was probably injected directly into the blood-vessels. In addition to the greater immediate safety to the patient, there is the further advantage of the absence of postoperative troubles, such as pneumonia and renal complications, which add to the remote dangers of general anesthesia. The absence of disagreeable after-effects shortens convalescence and adds to the general comfort of the patient. Patients will often submit to operations that can be done under local anesthesia, when they would hesitate if they had to be put to sleep. It is often an advantage to the surgeon to have the patient awake and conscious, for instance, in goiter operations, as the patient can talk, and thus insure the safety of the recurrent laryngeal nerve. It is also a great advantage to the surgeon not to have an anesthetist in the way during operations on the face and neck.

The disadvantages of the method are said to be: 1, That it is time consuming; 2, failure to secure complete anesthesia; 3, occasional necessity to extend operation beyond anesthetic field; 4, anesthesia may wear off before the operation is complete.

Concerning the time element, if the operator himself has to make all of the injections, in some cases it will take more of his time than it would to have the patient put to sleep by an anesthetist. In minor cases done under infiltration this does not apply, but where large nerve trunks are blocked it is necessary to wait a few minutes for the anesthesia to become complete; but if the operator has an assistant who can give the injections just as he has an anesthetist to put the patient to sleep, there will be no time lost.

Failure to secure complete anesthesia in blocking is due to imperfect technic. The solution has failed to come in contact with the nerve trunk. As this can always be determined before the operation is begun, it simply means that another effort should be made to reach the nerves to be blocked.

As it is not always possible to determine the exact limitation of an operation, it is better to block where feasible than to infiltrate, on account of the larger field of anesthesia which it gives. Should it be necessary to invade an unblocked area that cannot be anesthetized locally, one must resort to gas or other general anesthetic.

If the composition of the solution used is varied according to the character of the operation to be done, there is little danger of the anesthesia wearing off before the completion of the operation, as it can be made to last from two to four hours or even longer.

The use of too strong solutions of quinin and urea hydrochlorid may cause delayed union of the wound or even sloughing, but with procain

or apothesin this does not occur unless the solution has not been thoroughly sterilized, or the wound becomes infected from some other source. It is possible for sloughing to result from the addition of too much epinephrin to the solution, but this is easily avoidable.

So far as the general condition of the patient is concerned, there are no special contraindications to the use of local anesthesia. It may be used in the aged, in the nephritic, or in those with cardiovascular or pulmonary disease; it may be used in children who are not too young to be tractable and there is no definite limit in this respect. I have operated on children as young as four years of age without any trouble. All that is necessary is to secure their confidence and not hurt them.

SPECIAL SECTION

In selecting the method to be employed in a particular case one must be guided by the character of the operation and the anatomic relations of the part. In minor operations involving but a small area it is simpler and easier to infiltrate, while in more extensive operations it is better to block if the region permits it. The extremities, upper and lower, may be completely anesthetized by blocking. For the upper extremity the brachial plexus should be injected at the root of the neck. The method of Kulenkampf[4] is the one usually followed. A small wheal is made in the skin just above the middle of the clavicle and posterior to the external jugular vein. A long fine needle is then introduced and passed in a direction backward, inward, and slightly downward in a line which projected would strike the spinous process of the second dorsal vertebra. The plexus is reached slightly above and posterior to the subclavian artery, the location of which should be determined previously by palpation. The electric device and insulated needle already mentioned aid materially in locating the nerves. From 5 to 10 mils of a $1\frac{1}{2}$ per cent. solution should be injected and the needle allowed to remain in place for a few minutes to see if the anesthesia becomes complete. Should the anesthesia not be sufficient, more of the solution may be injected without the necessity of reintroducing the needle. When a satisfactory anesthesia has been obtained the needle is withdrawn. The anesthesia will involve the entire arm, with the exception of the region about the top and anterior part of the shoulder, which is supplied by the supraclavicular branches of the cervical plexus, and a small area on the inner side of the arm, which is supplied by the intercostohumeral nerve. It is necessary to block the plexus only in operations of some magnitude, such as amputation of the arm or forearm, or an operation on the elbow or on the bones. In minor operations on the fingers it is simpler to inject the nerves at the junction of the lateral and the dorsal and plantar surfaces at the base of the fingers. If the hand is involved, the median and ulnar nerves may be blocked just above the elbow or the ulnar posterior to the inner condyle, and the median beneath the tendon of the palmaris longus a few centimeters above the wrist, and the radial to the radial side of the radial artery.

The entire lower extremity may be anesthetized by blocking the

lesser sciatic at the middle of the lower edge of the gluteal fold, the great sciatic beneath the gluteus maximus muscle midway between the tuberosity of the ischium and the great trochanter; the external cutaneous to the inner side and below the anterior superior spine of the ilium; the anterior crural to the outer side of the femoral artery just below Poupart's ligament, and the obdurator as it lies on the adductor brevis beneath the pectineus muscle. With this blocking any operation may be done on the lower extremity, including amputations through the thigh, which I have done a number of times. The method is to be recommended, particularly in the old and feeble, with so-called senile gangrene. If the operation is entirely below the knee it will be necessary to block only the great sciatic and the anterior crural. In operations on the knee, such as suturing a fractured patella, only the anterior crural and the external cutaneous need be blocked. Minor operations on the foot, such as amputation of a toe or the removal of a bunion, may be done under simple infiltration.

Blocking the anterior and lateral regions of the neck is a very satisfactory procedure. This entire region is supplied by branches of the cervical plexus, which are easily reached just posterior to the posterior border of the sternocleidomastoid muscle above the crossing of the external jugular vein. The needle should penetrate the deep fascia, and if the entire region is to be blocked the solution should be injected up and down from this point, so as to include the upper and lower branches as well as the transverse. Both sides should be injected if the operation is to cross the midline. Under this anesthesia practically all operable goiters may be removed. The vessels entering the upper pole of the thyroid are sensitive, and pain is experienced when they are ligated and divided unless they are blocked. This may be done by passing the needle down to the thyrohyoid membrane just below the posterior end of the hyoid bone and injecting 3 or 4 mils of the solution. Gross movements of or pulling on the trachea are felt by the patient and give rise to a sensation of suffocation, but if the cause of this sensation is explained in advance and the patient assured that there is not the slightest danger, it will be disregarded by the most timid. It is quite remarkable how well patients stand extensive operations on the thyroid under blocking.

The same method of blocking may be used for any operation on the anterolateral region of the neck, such as the removal of tumors, tuberculous glands, tracheotomy, laryngotomy, laryngectomy, etc. It is surprising what a comparatively simple operation laryngectomy becomes under blocking when one is relieved of the annoyance due to the presence of the anesthetist and his apparatus. In doing a laryngectomy it will be necessary to infiltrate a little about the pharynx and the region supplied by the glossopharyngeal and vagus when this part of the operation is reached.

In operations on the face it will be necessary to block one or more branches of the fifth nerve and the upper branches of the cervical plexus, the latter nerves supplying part of the cheek and the region about the

angle of the jaw and beneath the chin. The supra-orbital and supra-trochlear nerves are reached at the supra-orbital foramen and slightly internal to it. The second division of the fifth may be reached at the infra-orbital foramen, or more deeply by introducing a needle at the angle of junction between the upper border of the zygoma and the posterior border of the malar bone. The needle should pass directly inward until it strikes the sphenoid bone. The point of the needle should then be depressed until it will pass under the sphenoid into the sphenomaxillary fossa, when it will be found in contact with the nerve as it escapes from the foramen rotundum. The mandibular branch may be blocked just before it enters the dental foramen on the inner surface of the ramus of the mandible. The needle should be introduced about 1 cm. above the grinding surface of the last molar and posterior to the oblique line. The direction of the needle should be on a line with the lower second bicuspid tooth of the opposite side. The point of the needle should follow the bone backward and slightly upward, a distance of about 2 cm., when it will lie in contact with the nerve. If only the terminal branches of the nerve are to be blocked they may be reached as they escape from the dental foramen. The method of reaching the upper branches of the cervical plexus has already been mentioned. Under this blocking plastic operations on the face may be done and operations on the bony structures and antrum.

Operations on the breast may be divided into two classes; 1, The removal of simple benign growths from the breast; 2, the complete removal of the breast with the pectoral muscles and the axillary glands for malignancy. Operations of the first class may be done very easily without pain by infiltrating subcutaneously the line of incision and the injection of from 20 to 30 mils of a 0.5 per cent. solution in the loose submammary space. The incision should follow the crease marking the junction of the breast with the chest wall, so that the scar will be as inconspicuous as possible. It may be made entirely below the breast, or below and to the outer side, according to the location of the growth to be removed, but it should not be made over the gland itself. The incision extends into the loose space between the breast and the pectoral muscle. The breast is turned up, the growth removed through the posterior surface; the space left is closed with catgut sutures, the breast returned to place, and the incision closed. This may all be done under simple infiltration. The complete operation for malignancy, however, requires extensive blocking. The anterior wall of the chest receives its nerve supply from three sources—the cervical plexus, the brachial plexus, and the intercostal nerves. Descending branches of the cervical plexus supply the skin almost as far down as the nipple, being overlapped by branches from the intercostal nerves. Branches from the brachial plexus supply the pectoral muscles, and these muscles are decidedly sensitive, and the intercostal nerves supply the breast itself and the remainder of the skin. The second to the sixth or seventh intercostal nerves are blocked posteriorly soon after their exit from the intervetebral foramina. A small wheal is made in the skin a little

external to the angle of the second rib. Through the wheal a long needle is introduced and passed downward subcutaneously as far as the lowermost rib to be blocked. As the needle is withdrawn the dilute solution is injected, thus anesthetizing a strip of skin through which the needle may subsequently be introduced without pain. A needle is then introduced through the first wheal and passed in a direction inward and slightly backward until it strikes the inferior border of the rib just posterior to the angle. The point of the needle is depressed slightly, so as to pass under the rib, and introduced parallel with the rib for a distance of from 2 to 3 cm., when it will be found to lie in contact with the nerve shortly after its escape from the intervertebral foramen. From 5 to 8 mils of a 0.75 per cent. solution is injected and the needle left in place while another similar needle is introduced in the same manner to the next nerve lower down. The first needle left in place acts as a guide and facilitates the introduction of the second one. The first needle is then withdrawn and used to block the next nerve, while the second needle remains in place. This procedure is repeated until as many of the intercostal nerves are blocked as may be necessary. The descending branches of the cervical plexus are blocked in the manner previously mentioned. The brachial plexus may then be blocked after the method of Kulenkampf. It will now be found that the entire wall of the chest, the axilla, and supraclavicular region are completely anesthetized, so that the most extensive operation desired may be performed, including the removal of the pectoral muscles, the axillary gland, and the supraclavicular glands if thought necessary.

Concerning the sensibility of the abdominal organs the reader is referred to Vol. V, page 1070. The abdominal cavity may be opened at any point by infiltrating the wall, but the amount of work that can be done therein depends upon the organ involved and the character of the operation, as well as the experience of the operator. If one bear in mind the fact that most of the organs themselves are not sensitive to ordinary trauma, but that the parietal peritoneum at all points is very sensitive, it will not be difficult to outline operative limitations under simple infiltration anesthesia of the abdominal wall. Although the organs themselves are not sensitive, most of them have peritoneal reflections which spread out on the parietes, and manipulation of or drawing on any of these is painful. There is also an indefinite sense of pain or discomfort when the abdomen is opened and the organs manipulated, even though the parietal peritoneum be not interfered with. This latter sensation may be eliminated by blocking the splanchnic nerves in addition to the spinal nerves, which can be done by blocking the dorsal nerves from the fifth down on both sides as they escape from the intervertebral foramina and before the communicating branches to the thoracic ganglia are given off. The splanchnics have also been blocked a few times after they pass through the diaphragm into the abdominal cavity. Both of these methods are difficult to carry out successfully, but when well done the anesthesia in the abdominal cavity is complete, and practically any operation therein may be done without

pain. Many operations within the abdomen, however, may be done quite satisfactorily by blocking the abdominal wall alone, as outlined in Vol. V, page 1071.

Blocking the sacral plexus by intrasacral injection is a very useful and satisfactory procedure. The anesthesia which results involves the area of distribution of the coccygeal and sacral nerves, and includes the pelvic organs, genitals, the perineum, and a saddle-shaped area on the buttocks, and the posterior surface of the thighs even to the full extent of the distribution of the great sciatic nerve. The needle is introduced into the sacral canal through the hiatus which exists in the dorsal wall of the canal at the caudal end of the sacrum. This hiatus, which is due to a failure of the dorsal arches of the sacral segments to coalesce, varies greatly in size, depending upon the degree of arrest in the development of the dorsal arches. If only the last or fifth arch is wanting, the opening is rather small and roundish or ovalish in shape. If both the fifth and fourth are wanting, the opening is much larger and triangular in shape. The opening can usually be felt and its size outlined with the tip of the finger. The best guide to the opening is the last sacral spinous process. The depression just caudad to this spine marks the location to the opening, which normally is closed by a dense fibrous membrane. There is some danger of breaking the ordinary hollow needle in trying to push it through this dense membrane. To guard against this accident, which has occurred twice to me, I have had made a small trocar (Fig. 638), the cannula being of soft metal and the stilet of hard steel. The trocar is introduced in the following manner: The patient is placed on the right side with the thighs well flexed. The dorsal surface of the sacrum is carefully examined to determine the location and size of the hiatus, the symmetry or asymmetry of the sacrum, its degree of curvature, etc. The sacrococcygeal junction is located by moving the coccyx. With a small hypodermic syringe a wheal is made in the skin over the hiatus and the subcutaneous tissue infiltrated down to the dense membrane. The trocar is then introduced down to the dense membrane, which is readily recognized as the point of the instrument penetrates it. If the trocar is felt to penetrate this membrane and enter a free cavity it is probably in the canal. It should then be pushed on in the direction of the canal until the point is felt to impinge against bone, which should be the curved dorsal wall of the canal. The trocar is then withdrawn about 1 cm. and the stilet removed. If at the end of a few seconds no blood or spinal fluid escape

Fig. 638.—Sacral Trocar.

from the cannula the solution may be injected. If blood or fluid escape, it indicates that the point of the cannula is in a large vein or the spinal sac, and no injection should be made until the location of the cannula has been changed so that no blood or fluid escapes. From 10 to 15 mils of a 1 per cent. solution may then be injected. The solution should flow in easily without resistance. If it requires any force to inject the solution it is almost certain that the cannula is not in the canal. After injecting the first 10 or 15 mils the cannula is allowed to remain in place, and at the end of a few minutes the skin is tested to see if anesthesia is appearing. The anesthesia begins at the point of puncture and extends gradually toward the perineum. If it is found that anesthesia is developing as indicated, it is positive evidence that the cannula is in the proper place and the remainder of the solution may be slowly injected. Ordinarily from 40 to 50 mils of the solution are sufficient, but if a very high anesthesia is desired, more may be used. After the solution is injected the cannula is withdrawn and the patient placed on the back with the hips slightly elevated on a pillow. Anesthesia is usually complete in from fifteen to twenty minutes. Under this anesthesia any operation involving the region or organs mentioned may be done without pain. It is ideal for operations on the rectum, perineum or vagina, and for prostatectomy combined with infiltration above if the suprapubic route is followed.

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CHAPTER LXI

SUBARACHNOID (SPINAL) ANESTHESIA*

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PHYSIOLOGY

A not inconsiderable part of the grave differences of opinion which pervade the discussions of the value of spinal anesthesia have been due to the neglect to study the physiologic effects of this method as worked out both clinically and in the laboratory. In 1907 Barker demonstrated that the diffusion of solutions introduced into the subarachnoid space was influenced by gravity and also by the specific gravity of the solution thus introduced as compared with the spinal fluid. Many observors have, however, failed to draw the appropriate conclusions from these observations, and have apparently been surprised because stovain, with a specific gravity of 1.0064, behaves quite differently from tropococain, with a specific gravity of 1.0106, and novocain, with a specific gravity of 1.0090. Too little attention has been paid to the publication of Smith and Porter, in which it was shown that if anesthesia of the dorsal nerve roots was produced a very sharp and sometimes very great fall in blood-pressure resulted. These observations, however, have a most important bearing upon the safety with which the method can be employed, and, in fact, account for substantially all the dangers attending the method and the contraindications to its use. Thus, obviously, if the condition of the patient is such that a fall in blood-pressure is undesirable or dangerous, this method cannot be used for the production of anesthesia in the abdominal region, since splanchnic paralysis and fall of blood-pressure will inevitably follow. Again, operations which require elevation of the pelvis involve increasing risk from misbehavior of the anesthetic, as the level of anesthesia will certainly rise higher than if the horizontal position is maintained, and may reach a dangerous height. Finally, the bulk of the solution as well as the point at which it is injected have important bearing on the level to which anesthesia will rise, and the routine employment of one technic for the purpose of producing anesthesia at various levels is not logical.

CHOICE OF DRUGS

Choice must be made at the present time from among the following four drugs: Stovain, tropacocain, novocain, and apothesin.

* Supplementary to Chapter LXXXI, Vol. V, p. 1045, and Chapter CLII, Vol. VI, p. 981.

Stovain has perhaps been most largely used, but has proved notably unreliable, a result which may be in part due to the fact that as it has a low specific gravity its diffusion in the subarachnoid space depends almost entirely upon the law of diffusability of liquids, and is unaffected by gravity, which is probably the most important factor in controlling the level of anesthesia.

Tropacocain is not open to this objection. In our hands it proved a satisfactory drug in the days when it was readily obtainable, but appeared to be somewhat less potent than novocain and having no important superiority. Since it was a German preparation, it became difficult to obtain, and its use was properly abandoned.

Novocain has, on the whole, enjoyed the largest popularity. Its toxicity is very slight. Its specific gravity is relatively high and the solution is, therefore, easily controllable by gravity. It has good anesthetic properties.

The difficulty or impossibility of obtaining the drug in reliable preparation during the war led to the production of **apothesin,** which has now been in use for about three years. A considerable literature appears to warrant the belief that its properties are essentially similar to those of the former German preparations of novocain, and the indication is that its anesthetic properties are as good and that its toxicity is very slight, certainly not greater than novocain. Our own rather limited experience has been entirely satisfactory, and if further trial bears out this view, it is likely to become the drug of election.

For spinal anesthesia a 5 per cent. solution of all these four drugs is commonly employed, and the amount actually given should be varied according to indications, which will be later discussed.

The value of adding adrenalin to the solution is still unsettled. We cannot agree with Major Houghton that the question has now been settled, nor follow his argument that the situation is entirely different from that of infiltration anesthesia. It may be admitted that this drug will not have the effect of anchoring the solution in a definite area, but clearly it has the effect of contracting the blood-vessels not only in but about the nerve trunks, and the work of Smith and Porter strongly suggests that it increases the duration of anesthesia. On the whole, we believe that its use is free from objections and has some effect in prolonging anesthesia and thereby increasing the efficiency of relatively small doses.

TECHNIC

Position of the Patient.—Two positions have been commonly used, one in which the patient sits upon the edge of a table with his legs hanging down and the back arched backward; the other, lying on the side with the knees drawn up and the back arched as much as possible. The sitting position we have abandoned because it seems to serve no necessary purpose and undoubtedly subjects the patient to some strain, especially in feeble or nervous people, which is avoidable and, therefore, undesirable (Fig. 639). The advantage thought to be gained by the sitting position was the prevention of the anesthesia from rising to too high

a level, but this can be avoided by slightly raising the patient's shoulders when lying on the side and by the use of concentrated solutions in small quantity. We have never observed any objectionable symptoms from

FIG. 639.—THE LOWER TOWEL HALF COVERS THE FOURTH LUMBAR SPINE. (Houghton.)

the drug rising to too high a level except in cases in which the sitting position would have been inappropriate, as it was desired to get the anesthesia high and gravity would in any case have had to be used.

FIG. 640.—THE ELEVATION OF HEAD AND PELVIS ARE HERE SEEN. (Houghton.)

We have come to use entirely the lateral position (Fig. 640) and have made our injections strictly in the middle line, the approach from slightly to one side of the midline being believed to have no impor-

tant advantages, and occasionally to be more difficult for the inexperienced.

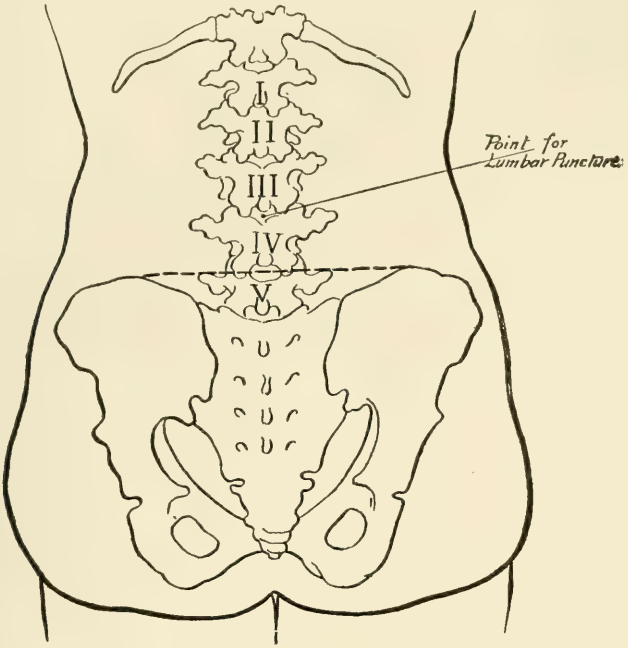

Fig. 641.—The Point for Lumbar Puncture. (Zachrisson.)

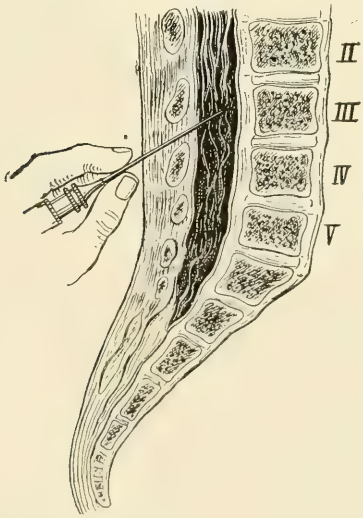

Fig. 642.—Side View of Lumbar Puncture Between the Third and Fourth Lumbar Vertebræ. (Zachrisson.)

Landmarks.—The guiding landmark in this region from which all calculations may be satisfactorily made is the spinous process of the

fourth lumbar vertebra which lies on a line between the highest points of the crests of the ilia. The lowest space available for injection is between the fourth and fifth vertebræ. The space most commonly used for "low" injections is between the third and fourth, which lies just above the line described, and the space between the second and third is readily identified in practically all cases (Figs. 641, 642). It is exceedingly rare to find a patient so corpulent that the spinous process of the second, third, and fourth lumbar vertebræ cannot be readily identified.

Factors Influencing the Level of Anesthesia.—There are three important facts which influence the particular level to which the anesthetic will rise:

1. **The Site of Injection.**—Generally speaking, the higher the level at which the injection is made, the higher the anesthesia will rise, other factors being the same. Though Jonnesco some years ago advocated the injection for the purpose of producing spinal anesthesia at various levels, even up to the cervical region, his results were so unsatisfactory, and even those which he claimed were so rarely obtained by other observers, that his method never found favor. In practice, injections are now made only into the subarachnoid space below the level of the termination of the cord, and practically between the second and third, the third and fourth, and the fourth and fifth lumbar vertebræ. Injections made between the second and third may be expected to involve more than half of the dorsal nerve roots and produce anesthesia if desired up to the level of the xiphoid or nipple. In the same way injections made between the fourth and fifth with similar technic are likely to be confined to the sacral and lumbar roots, and produce anesthesia only of the lower extremities, perineum, bladder, and anus.

2. **Position of the Patient.**—If the patient's spine is exactly or practically parallel with the table, so that gravity is inoperative, the anesthesia will take effect only in the immediate neighborhood of the site of injection and will diffuse upward only to a slight degree. If the patient's hips are raised anesthesia will rise to a higher level, and this may be controlled by raising the shoulders so as to prevent diffusion above the middorsal region. If it is desired to confine the anesthetic to the lumbar and sacral roots the patient's shoulders should be elevated and the hips allowed to remain stationary.

3. **Size of Dose and Amount of Fluid Used.**—The work of Smith and Porter appears to show that the "bulk of fluid is, on the whole, a factor of greater importance than the strength of the solution." Therefore, if it is desired to get the drug sharply localized to the lower roots, a small amount of fluid should be used, whereas, if it is desired to get anesthesia at higher levels, the amount of dilution should be increased up to 3 or 4 or even 5 c.c. Generally speaking, in adults the dose of the drug should vary from 1 to 2 grains, being influenced by the size, strength, and general condition of the patient. We commonly use about $1\frac{1}{2}$ grains and depend upon dilution chiefly to influence the level of anesthesia. More specifically our technic is as follows:

1. For anesthesia of the perineum, bladder, anus, and lower ex-

tremity—with the exception of the triangle of skin on the front of the thigh roughly corresponding to Scarpa's triangle—we make the injection between the fourth and fifth lumbar vertebræ, use 1½ grains of novocain or apothesin dissolved in 2 c.c. of distilled water and diluted with an equal amount of spinal fluid. The patient's shoulders are slightly elevated.

2. To produce anesthesia of the scrotum, inguinal region, and abdomen below the umbilicus the injection is made between the third and fourth lumbar vertebræ, using about the same dose of the drug diluted with a little more spinal fluid, and with the patient's hips slightly elevated and the shoulders also slightly raised, to prevent the anesthesia rising undesirably high.

3. To produce anesthesia over the whole abdominal area including that portion above the umbilicus, so that operations upon the stomach and gall-bladder can be satisfactorily done, the injection should be made between the second and third lumbar vertebræ, using about 1½ to 2 grains of the drug diluted to 5 or 6 c.c., with some elevation of the hips and moderate elevation of the shoulders. Our experience, however, with anesthesia at this level is small, as we do not regard it as safe (see Contraindications).

TECHNIC OF INJECTION

Though the technic of injection is now widely known, and most operators employ roughly similar technic, ours departs from that of others in some particulars which may be of interest. As above mentioned, we always use the lateral position. The use of a local anesthetic in the skin and deeper tissues appears to add considerably to the comfort of the patient and is, therefore, desirable. For this purpose we anesthetize the point of injection and the tissues underlying it with a 1 per cent. solution of novocain or apothesin. The "spinal" needle is then inserted strictly in the middle line, pushed forward until it is deeply embedded in the tissues, and the stylet is then withdrawn. The needle is pushed forward until it enters the subarachnoid space and fluid runs freely. The syringe containing the anesthetic, in bulk about 1½ to 2 c.c., is then attached and sufficient spinal fluid is drawn up into the syringe to produce the desired dilution. The syringe is then detached from the needle to be sure that spinal fluid still flows freely. This is an important precaution, as in the process of drawing up spinal fluid into the syringe the position of the needle point is occasionally altered so that it is partially out of the subarachnoid space. A strict observance of this precaution will avoid occasionally unsatisfactory anesthesia. This maneuver having been completed, the syringe is again fitted to the needle and the injection made slowly. Definite evidence of anesthesia will appear promptly if the technic has been accurately carried out. In a small number of cases partial or incomplete anesthesia results, probably always due to errors in technic which are not appreciated. When this occurs the operator may choose between abandonment of the method and the making of a second injection in a higher or lower space.

With drugs of as low toxicity as novocain and apothesin second injections we believe to be unobjectionable.

INDICATIONS AND CONTRAINDICATIONS

It has been customary to limit the use of spinal anesthesia to those cases in which a general anesthetic was for some reason or other contraindicated. This limitation arose from failure to distinguish between the definitely dangerous attempts to produce anesthesia at a high level and the quite safe production of anesthesia at low levels. Thus we have used spinal anesthesia as the anesthetic of election for all cases of cystoscopy which would otherwise require a general anesthetic. In these cases no anesthesia is produced above the level of the pubes, and we believe spinal anesthesia to be as safe as or safer than any general anesthetic now in use. Moreover, it produces better anesthesia of the bladder than any general anesthetic, for it paralyzes the nerve endings in the bladder and consequently abolishes bladder spasms and contractions, which no general anesthetic will do unless pushed to almost dangerous depths. Anesthesia of the bladder is particularly easy to obtain by this method and failure has been of the utmost rarity. The same degree of safety exists in anesthesia of the perineum, anus, and lower extremity, but particularly of the lower extremity occasionally unsatisfactory anesthesia modifies its usefulness. For most of the operations upon these regions general anesthesia is unobjectionable and many patients will prefer (so to speak) not to be present at their own operations.

Spinal anesthesia may be regarded as the anesthetic of election, however, in this group of cases whenever pulmonary conditions, age, or shock make general anesthesia undesirable. The same degree of safety cannot, however, be predicted when it is desired to obtain anesthesia in any area supplied by the dorsal nerve roots, because the paralysis of these roots will involve splanchnic paralysis over the same area, and this will often be followed by a fall of blood-pressure of greater or less amount, according to the extent of the paralysis and the ability of the patient to equalize blood-pressure in spite of splanchnic paralysis. Those patients in whom well-marked anesthesia up to a level midway between the umbilicus and the xiphoid occurs will at times exhibit a group of symptoms indistinguishable from those ordinarily called shock. Blood-pressure falls rapidly and sometimes greatly, the pulse may be either slow or rapid, but is weak. The patient is pale, sweating, more or less distressed. Without involving ourselves in a discussion of whether these symptoms are, in fact, due to shock, they are strikingly similar, and though they pass in a relatively short time, generally within two hours, they are not wholly free from objection. It has been our experience that in relatively young patients this group of symptoms when it occurs is comparatively harmless, whereas in patients advanced in years, with varying degrees of arteriosclerosis and damaged hearts, the circulation does not return to its original reasonably satisfactory condition, and, in some cases at least, we have regarded it as a contributory

factor in the death of these patients some days later from cardiac or pulmonary complications. These symptoms are more common the higher the level of the anesthesia, and though many observers have done considerable numbers of operations in the abdomen above the level of the umbilicus with this method of anesthesia, it cannot be regarded as a safe procedure, and should be undertaken cautiously and only in the presence of a positive contraindication to any and all general anesthetics. Even under these conditions it does not necessarily become the method of election, as the broadening field of local and "block" anesthesia is rapidly supplanting it. In equally skilful hands local anesthesia is probably safer and a better method than spinal anesthesia at any level likely to involve much or complete splanchnic paralysis.

Most discussion will center over the use of this method in operations in the intermediate zone—pubes to umbilicus—as it will be generally accepted that the higher levels are dangerous and the lower levels safe. For operations below the umbilicus, for hernias, and operations upon the scrotum spinal anesthesia is a satisfactory and relatively safe method. On the other hand, local anesthesia, though technically more difficult, is nearly if not quite as satisfactory, and is likely progressively to push spinal anesthesia from this field.

For operations upon the lower extremity, particularly those with extensive involvement of the large bones and joints, local anesthesia is more difficult, and in no respects more satisfactory. The same applies with even greater force to examinations of the bladder, to operations upon the urethra, male perineum and prostate by the infrapubic route, and in the hands of those who are desirous of fitting their anesthetic nicely to the particular problem involved is likely to remain the anesthetic of election. For operations upon the anus and female perineum it is notably more satisfactory than local anesthesia, more certain than sacral anesthesia, and may properly be left to the discretion of the patient if there is no contraindication of any kind to general anesthesia.

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CHAPTER LXII

POISON GAS IN WARFARE

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"In the matter of making an end of the enemy's forces by violence it is an incontestable and self-evident rule that the right of killing and annihilating, in regard to the hostile combatants is inherent in the war power, and its organs; that all means which modern inventions afford, including the fullest, most dangerous, and most massive means of destruction, may be utilized. These last, just because they attain the object of war as quickly as possible, are on that account to be regarded as indispensable, and, when closely considered, the most humane" (German War Book, quoted from *The Military Surgeon*, 1915, xxxvii, p. 422).

This paragraph of Teutonic gospel stands as the reason for the recrudescence of measures of warfare analogous to the Greek fire of the ancients and the stink-pots of the Chinese. But, as the alchemist was supplanted by the chemist and superstition fled before science, so what was in early times, to a large extent at least, a moral factor in combat, came under the exact findings of the laboratory to be a most important one in the decision of issues by arms.

Whatever the German justification for the reintroduction of a means of warfare which had been tactily accepted as belonging to a barbarous past, there is no doubt that the attack at Ypres on the Canadians and French came as a complete surprise to the Allies, and found them altogether without defence against this mode of combat. Nor does there seem to be any doubt that its use by the Germans was the result of careful experiment covering a considerable length of time. It was no forlorn hope made use of to stem the tide of an unfavorable action, but altogether in accord with the tenets of the paragraph from the German War Book which heads this chapter and which declares in essence that the determination of the ethics of conflict rests with the individual powers.

The first gas attack, the one of April 22, 1915, was made with chlorin used as a wave, and probably the only reason that it did not count for a very decisive tactical success for Germany was due to the fact that it was not used save as a limited measure. Employed to the extent which gas was subsequently by any of the warring powers it is difficult to estimate the German advance, or to predicate the safety of the channel ports as a direct consequence of this assault. There are no exact details of the casualties in this engagement, but the statement has been

made (Spear) that 10,000 of the 12,000 Canadians holding the sector at the time were killed.

As the prevailing winds on the western front are westerly there was no opportunity for the Germans to resort again to this method of attack before December of the same year, and by that time the Allies had opportunity to provide a measure of protection in the form of masks which were in some degree effective in neutralizing the effect of the poison. It may be noted here that the prevalence of winds from the west, above referred to, acted as a boomerang to the Germans thereafter, both as to offense by the Allies and at times in respect to their own attacks, since in several recorded instances a sudden change of wind resulted in the gassing of their own trenches instead of those of their enemies.

As to the ethics of this means of warfare, there is much to be said. At the meeting of the Hague Conference in 1889 the question of the use of projectiles charged with asphyxiating gases was extensively considered, and of the twenty-six nations who were represented in the conference all save Great Britain and the United States agreed to the following clause: "The Contracting Powers agree to abstain from the use of projectiles the object if which is the diffusion of asphyxiating and deleterious gases." Germany was a subscriber to this clause, as were the other nations, with the exception of Great Britain and the United States. The two representatives of the United States Government at this conference were Admiral Mahan, of our Navy, and Mr. Andrew D. White, at one time Ambassador to France. Admiral Mahan gave as his reasons for refusing to subscribe to this clause the following, which I extract: (1) "That no shell emitting such gases is as yet in practical use, or has undergone adequate experiment; consequently, a vote taken now would be in ignorance of the facts as to whether the results would be of a decisive character, or whether injury in excess of that necessary to attain the end of warfare, the immediate disabling of the enemy, would be inflicted. (2) That the reproach . . . addressed against these supposed shells was equally uttered formerly against firearms and torpedoes, both of which are now employed without scruple. (3) That it was illogical and not demonstrably humane to be tender about asphyxiating men with gas when . . . it was allowable to blow the bottom out of an ironclad at midnight, throwing 400 or 500 into the sea to be choked by water, with scarcely the remotest chance of escape. If, and when, a shell emitting asphyxiating gases alone has been successfully produced, then, and not before, men will be able to vote intelligently on the subject."

Ambassador White was not in accordance with Admiral Mahan's views, but deferred to him, saying in part, "I am not satisfied with our attitude on this question; but what can a layman do when he has against him the foremost contemporary military and naval experts?"

At the meeting of the conference of 1907 Germany again subscribed to the clause prohibiting the use of asphyxiating gas, and at this conference Great Britain changed her vote to conform with those of the

majority of the conferees, but, the United States still adhered to the decision reached by Admiral Mahan.

It is to be especially noted that Germany at both of these conferences specifically and definitely placed herself on record as opposed to the use of this means in warfare. It is not necessary to call attention to the fact that in spite of being one of the Powers to express this disapproval, she was the first to put into effect this prohibited method of warfare.

The sentence in Admiral Mahan's explanation of his vote—"a vote taken now would be in ignorance of the facts as to whether the results would be of a decisive character"—has had its answer in the statistics in regard to the steadily increasing use of this means of warfare, and the certainty that if the war had not reached its termination on November 11, 1918, it would almost certainly have proved one of the very decisive factors in the final result.

As to the efficacy of gas as a weapon, the following figures (Report of the Surgeon-General of the Army, 1919, pp. 48, 49) are worthy of consideration: "The reports that were received in this office prior to the compiling of this report show that 227,855 wounds were received in battle that required admission to hospital. . . . Of the total wounded, gas caused 31.36 per cent. The reports that have been tabulated show that 18,268 died in hospitals as the result of battle injuries. . . . Of the total deaths, gas caused 6.57 per cent." If we take these two percentages, irrespective of any reservations, two things are certainly apparent: First, that if any one cause is responsible for 31.36 per cent. of all casualties necessitating admission to hospital, this agent must receive grave consideration as a potent agent in offensive war. Second, that if it is, in addition, chargeable for only 6.57 per cent. of deaths, it is not so serious as a destroyer of human life as other engines of war which have the sanction of the Hague Convention.

In the initial stage of the use of gas its employment was limited to "wave gas" (Fig. 643), that is to say, the liberation of a cloud from containers placed in the trenches and governed by outlet pipes and siphons for emptying them of the gas which was stored in them under pressure. It was soon demonstrated that the limitations to its use in this manner were too many to accomplish the ends which were expected of it. The liberation of a cloud was dependent on meteorologic conditions; that is to say, the wind must not only be in a favorable direction to carry the cloud to the enemy's territory, but also not above a certain velocity per hour, in order that the cloud might be borne along the ground and not dissipated by a too rapid current.

The following, quoted from British records, is a summary of a series of gas attacks made by the Germans against the Russians during 1917:

"First attack, May 18th: On a front of 12 kilometers an attack was launched lasting twenty minutes. The distance between the trenches varied between 100 and 200 meters. There were evacuated 3 officers and 7735 men. There were left dead on the field 12 officers and 1080 men.

"Second attack, June 12th: There were evacuated 28 officers and 2034 men. The dead on the field were unknown, as the trenches were lost.

"Third attack, July 6th: Total evacuations and killed on the field 87 officers and 9913 men. In this attack the 21st Siberian Regiment had at the start a strength of 39 officers and 4310 men; after the attack they had left 4 officers and 400 men."

Of course, it must be understood that the element of surprise was important in this series, and further allowance must be made for the fact that the Russian measures of protection against gas were not thorough nor in any state of completion. However, as has been stated, the exigencies of modern war demanded a method of attack which was more certainly under the control of man, and increasing resort was had to the gas projectile. The last gas cloud attack by the Germans against

FIG. 643.—GAS WAVE. (Chemical Warfare Service, U. S. Army.)

the British occurred in August, 1916, and against the French on April 23, 1917, two years almost to the day after the loosing of the first attack at Ypres. The cloud had run its course as a means of attack; had passed its climacteric in spite of the fact that the clouds had increased in concentration and in poisonous properties. This was due to the constant and increasing protection afforded by the masks adopted by the Allies. After the decline of the use of cloud gas all development along the line of gas warfare was in the perfection of its use by artillery. This limit had probably not been reached at the signing of the armistice, and it remains for some future conflict to demonstrate the refinements of which this is capable. The limit to the dispersion of gas on a given target is only the number of guns which can be trained on it and the rapidity of their fire. Questions of caliber are those of economics rather than those of artillery, for there is no limitation in respect to the size of

the shell which may be so charged. As it was, definite tactics were evolved for the use of gas, these being built up on the experience gained in its use and occupying as definite a place in war as any of the tactical methods for the other arms of the service. Gas shells could be used for all purposes which were met by high explosives save in firing for demolition, and in many of the other uses were more effective than ordinary shells or shrapnel. Gas had a double effectiveness. Aside from its property as a disabling agency, it compelled the wearing of the mask by the troops which were assailed by it, and this in itself lowered their efficiency very markedly.

The practicability of the use of gas having been established by the attack at Ypres, the question to be decided was that of the development of this kind of warfare, and this naturally led to the adoption of gases which should be most effective for the use for which they were intended. Also, as has been mentioned previously, the utilization of a method of delivering them which should not be dependent on the vagaries of meteorologic conditions.

From this beginning it was merely a question of expansion, experiment, and progress to the use and adoption or rejection of other agents until experience had demonstrated which of them was of the greatest value. Attempts were made to conceal the nature of the gases used, but the inevitable incidence of the "dud" shell sooner or later gave, through the research laboratory, the clue to whatever new was used. Many lists of the gases used or supposed to have been used have been printed, and probably most complete among them is that published by Warthin and Weller in their very complete book on "Mustard Gas Poisoning." This list is made up, as stated, from those of Hill, Cervidalli, Gallo, Filippini, Vaughan, and others. The list, as printed by Warthin, is: "Acrolein, allyl-iso-thiocyanate, arsenic trichlorid, arsine, bromacetone, bromacetic ether, bromethyl-methylketone, bromid of benzl, bromid of xylyl, bromid of toluyl, bromin, carbon monoxid, carbonyl chlorid (phosgene), chloracetone, chlorin, chlorpicrin, cyanogen, dichlorethylsulphid (mustard gas), dichlormethylether, dimethylsulphate, diphenylchlorarsine, diphenylfluorarsine, ethyldichlorarsine, formaldehyd, hydrocyanic acid, hydrosulphuric acid, iodaceticether, iodacetone, methylchlorsulphonic acid, monochlormethylchloroformate (palite), nitrogen peroxid, phenylcarbylaminechlorid, phosphene, phosphorus trichlorid, sulphur dioxid and trioxid, and trichlormethylchloroformate (diphosgene or superpalite).

"Apparently, however, the poisons found to be the most effective in gas warfare were: bromethylmethylketone, carbonyl chlorid (phosgene), chlorin, chlorpicrin, dichlorethylsulphid (mustard gas), dichlormethylether, diphenylchlorarsine, ethyldichlorarsine, monochlormethylchloroformate (palite), trichlormethylchloroformate (diphosgene, superpalite), and xylyl bromid."

In this list no mention is made of brombenzyl cyanid, which was adopted by the Chemical Warfare Section of our own army as being more effective than any of the lacrimators in use by the other powers.

As evidence of this it may be stated that in a concentration of 1 in 20,000,000 this gas is unbearable within five minutes, and in a dilution of 1 in 100,000,000 is unbearable after thirty minutes, being relatively twenty times as potent as any of the others in use. It is also far more persistent. Hydrocyanic acid is dismissed by most writers with a few words and the intimation that it was never extensively employed. It is true that it did not find favor with the British and that our own forces had no great opinion of it as a lethal gas, but it is also true that the French, who were responsible for the development of the use of it, were at the beginning of the war highly enthusiastic in regard to it and up to the signing of the Armistice, so far as I can learn, did not relegate it to the list of those which had been tried and found wanting.

To go back to the list of gases given in the quotation from the book of Warthin and Weller. The list may be, for all practicable purposes, further reduced as far as consideration of the use of gas in warfare is concerned, for while a number were tried out, the final analysis demonstrated that the practical work was accomplished with a limited number.

The demands of tactical situations were responsible largely for the development of the different agents employed, and as they were brought out they assumed their places in the rôle which they were best fitted to serve. Of course, the primary object of any weapon of war is to kill, for when you strip this ugly business of its trappings, it is the side which kills the greatest number of its opponents which wins. According to this view it would have been the best tactics to employ no gas save that which had an almost certain lethal effect. But since the consummation of this end of warfare is not attainable at once nor by the employment of any one measure, there was a place for all those which injured or put the adversary out of commission, or undermined his strength or morale. The very existence of a gas attack was a blow at the morale of troops, though it became so much a matter of routine in the later state of the conflict that much of this element was lost and the effect on the morale was not appreciably greater than that of bombardment by any other agent. It did undoubtedly wear down the strength of those who had to support life in spite of it and through the defensive medium of the gas mask. The increased respiratory resistance consequent on the wearing of the mask is a very real tax, and when this has to be borne with for as long as eighteen hours there is no question that the physical condition of the troops is below par. In addition to this there was no mask that did not limit vision and make the carrying on of the usual duties of the soldier a much more burdensome proposition than when he was not so encumbered. Both sides took full advantage of this fact, and in addition to surprise attacks designed to catch the enemy unawares and incapacitate a number before he was able to don masks, the use of gas to harass was an important element. Areas back of the front were drenched with gas, lines of communication were systematically shelled at times when it was probable that they were most congested with traffic to the front or from the front. Hostile batteries were covered with clouds of it in order that the gunners might

have to fight their guns at a disadvantage in their masks. When it was not possible to kill, every opportunity was taken to wear down the strength of the opponent in this way. Much ingenuity was displayed in this form of bombardment, and advances in offence were met by improvements in defence, the two alternating in their supremacy.

In the first chapter of the struggle it was not a difficult matter to determine the onset of a gas bombardment because the shells had not the same sound on bursting that marked those charged with high explosive. The use of the gases which were markedly lighter or even a little lighter than air was seriously disturbed by the normal charge of melinite. With the advent of the later gases, notably dichlorethylsulphid and diphenylchlorarsine, this differentiation could not be made, since the use of a heavy charge was advisable in order to pulverize and disseminate in fine particles these heavy liquids which were not, in reality, gases. The Germans at first masked the use of the first named of these two gases by employing shells charged with high explosive at the same time. Then diphenylchlorarsine was found in bottles in shells charged with a full percentage of H. E. (the "blue cross" shell), and eventually it had to be assumed, until proved to the contrary, that every bombardment was gas. This assumption, at that, was a safe one, for according to Auld, of the British Gas Service, many bombardments were entirely of gas shells, some of them involving the firing of as many as 250,000 on a front in twenty-four hours, and finally he estimates that 25 per cent. of all German shells were filled with gas. The French Gas Service was asking for 35 per cent. of gas shells in 1917, and our own service at that time was endeavoring to secure the adoption of a quota of one-fourth of all loaded.

RESPIRATORY IRRITANT GASES

There are a number of gases which fall under this classification, but as the scope of this chapter is not adequate to deal *in extenso* with all the poisons which have been developed and tried out, it seems desirable to discuss only those which were accepted as most effective as war weapons and were most commonly used by the Germans and by the Allies. It should be stated again that in all classifications of gases the lines of demarcation, both in regard to physical properties and physiologic effects, are not hard and fast, and that one gas may have properties common to others in the listing.

The predominant characteristics, however, very properly govern their separation according to their special properties.

Under the heading of "Respiratory Irritants" the three which are of the first importance from the tactical standpoint, and therefore from that of the medical profession, are:

1. Phosgene.
2. Chlorin.
3. Chlorpicrin.

Phosgene

Carbonyl chlorid, $COCl_2$. *British and American designation*, "C. G."; *French*, "Collongite." This is a liquid, boiling at 47° F., and with an odor which has been likened to moldy hay. Because of its low boiling-point it will not remain on any terrain on which it is thrown for more than a few minutes, the limits commonly accepted being: in the open ten minutes, and in wooded country three hours. In accordance with this characteristic it is classed as a non-persistent gas in distinction to those of a higher boiling-point. It will form clouds of varying concentration depending on the manner in which it is thrown over, and a very heavy cloud may render positions dangerous 10 and even 12 kilometers from the point of attack. When used as a cloud gas, from cylinders, it is mixed with chlorin in order to obtain a mixed gas of high vapor pressure. In shells it is generally used pure. The Germans also mixed it with pumice, absorption in which retards its evaporation and makes it persistent for several hours. It has been used mixed with chlorpicrin and also with diphosgene and diphenylchlorarsine. It is probably the most deadly of the gases used in warfare. The concentrations necessary to produce death are shown in the following table:

Gas.	Exposure for five minutes.		Exposure for thirty minutes.		Exposure for two hours.	
	Concentration by volume.	Gm. per M^3.*	Concentration by volume.	Gm. per M^3.	Concentration by volume.	Gm. per M^3.
Phosgene.....	1 per 5000...	0.82	1 per 25,000..	0.16	1 per 100,000.	0.04

As shown by the figures of the above table, exposure to high concentrations for even a short time will cause severe casualties or even death, and much lower concentrations will also have serious effects. Its full effect is usually delayed for several hours, and exercise after exposure to this gas will render slight casualties much more serious or even fatal. Because of this effect men who have been gassed even slightly and who have experienced no symptoms of gas poisoning *must be prevented from taking any exercise whatever* if serious casualties are to be prevented. It is used entirely as a surprise gas, as high concentrations can be developed very rapidly. Its persistency is low, as has been mentioned, and it is therefore possible to follow up a phosgene attack with an infantry advance after a very short time.

Phosgene acts chiefly as a respiratory irritant. Very small doses scattered in the air cause coughing, watering of the eyes, and intense dyspnea. It differs from chlorin in that in small concentrations its influence is limited mainly to the terminal air cells of the lung. This effect leads to edema of the lungs, accompanied by the interference of the passage of oxygen inward, and consequent cyanosis, a grave condition, and often death. The first symptoms are dizziness and cyanosis

* *i. e.*, Grams per cubic meter.

on exertion. It usually takes some hours for the serious symptoms to develop and in the interval there may be no sign of danger.

The terminal air cells become filled up at the end of from twelve to twenty-four hours with serofibrinous exudation with some desquamated cells. The condition, therefore, is similar to that of bronchial pneumonia rather than the acute edema following poisoning by chlorin or stronger concentrations of phosgene.

During tests on man for the breaking-down concentration, symptoms noted at this point were chiefly cough from excessive irritation, and in some cases a feeling of suffocation. A few complained of nausea, but this was not a constant symptom.

Warthin says in "Mustard Gas Poisoning": "In the experimental phosgene gassing of rabbits and cats Bilancioni found the most severe contact lesions, the mucosa of larynx, trachea, and larger bronchi in a state of necrobiosis and desquamating in large strips. There was marked pulmonary œdema and congestion, with thrombosis and hemorrhagic infarction." In some cases the intrinsic laryngeal muscles showed fragmentation, which he thinks may have been due to or favored by the convulsive opening or closing of the larynx. The laryngeal lesions, particularly the hemorrhages into the submucosa, and the extreme pulmonary edema he considers the most important features.

Similar pulmonary lesions are found in the human cases, and the occurrence of thrombosis is also repeatedly mentioned. The Italian writers emphasize the frequency of thrombosis of mesenteric vessels, resulting in some cases in a diffuse necrotic enteritis and localized peritonitis. Punctiform hemorrhages in the brain are also a frequent finding. These are considered by Mott as of embolic origin, possibly due to pigment granules of altered hemoglobin. In the brain of 2 cases of drift gas poisoning he found the white matter peppered with innumerable hemorrhages about the size of a pinhead. These were microscopically like those of carbon monoxid poisoning save that the hemoglobin appeared to have been largely converted into chocolate-colored granules, a change which he thinks may have been due to the action of hydrochloric acid liberated from the phosgene in converting the hemoglobin into acid hematin.

The main clinical features of phosgene poisoning may be summed up as follows:

"1. Catching of the breath, choking, and coughing immediately after exposure to the gas.

"2. Inability to expand the chest in a full breath after removal from the poisoned air.

"3. Vomiting, hurried shallow respiration, and sometimes coughing with an abundant expectoration following. Pain is felt behind the sternum and across the lower part of the chest. Fine râles are heard in the axilla and over the back.

"4. Cyanosis next appears, in association either with a full venous congestion or with the pallid face of circulatory failure. The development of these dangerous symptoms may occur after many hours' delay,

Fig. 644.—Blue Type of Asphyxia from Phosgene Poisoning, with Intense Venous Congestion.

History of case: Drawing made early on second day after gassing when there was copious frothy sputum, frequent cough, and hurried shallow respiration of 40 to 48, with temperature of 101° F. and pulse 100. He soon made a complete recovery.

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Fig. 645.—Pallid Type of Asphyxia from Phosgene Poisoning, with Circulatory Failure.

History of case: Drawing made on second day after gassing when there was profuse frothy expectoration, hurried shallow breathing of 50 a minute, and a rapid running pulse of 132. The patient died two hours later.

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and sometimes with unexpected rapidity in an apparently slight case as the result of muscular effort.

"5. Death, which may or may not be preceded by mild delirium or unconsciousness, rarely occurs after the first or second day." (British Official Document.)

The blue type of asphyxia (Fig. 644) with venous congestion is met with more frequently in cases of chlorin poisoning, but is not infrequently found as a result of phosgene. The pulse is strong and full and the patient is entirely conscious. He is very restless and complains of pain in the chest. There is explosive coughing from time to time, with expectoration. In this condition there is edema of the lung.

The pale type of asphyxia (Fig. 645) is more characteristic of phosgene poisoning and may occur as an early effect of the gas, or as a secondary stage of the venous congestion mentioned above. The patient has a typical leaden-hued pallor, in marked contrast to the florid color in the blue type, and is restless and not infrequently semidelirious. The skin is either hot or cold and generally dry. The pulse is small, weak and rapid, and the breathing much accelerated and shallow, and with it may be heard moist tracheal râles. Physical examination of the chest shows a condition similar to that in the blue type; dulness on percussion, and fine moist râles heard more clearly posteriorly. Pulmonary edema is present, but is masked by the numerous foci of emphysema which exist.

The following notes given to me in 1917 by the author, Major Charles F. Hoover, are clear and to the point and set forth the symptomatology of phosgene poisoning. It is not known whether they have been reproduced, nor whether Major Hoover has changed his views in regard to the value of the administration of oxygen.

Analysis of the Objective Clinical Signs in Phosgene Poisoning.—"For diagnostic and therapeutic purposes the following aspects of phosgene poisoning require differential diagnosis in the Field Ambulance Dressing Stations and C. C. S. The medical officer should learn to recognize what factors the following pathologic lesions may be contributing in any case of phosgene poisoning: A. Pulmonary œdema. B. Dilatation of the right side of the heart. C. Bronchiolar spasm. D. Pulmonary emphysema. E. Bronchopneumonia. F. Hemorrhage in the brain and cord.

"A. Recognition of pulmonary œdema is not attended with any difficulty. Air hunger, gray cyanosis, blue cyanosis, and bubbling râles throughout the lung are signs so striking and simple they cannot be overlooked. Herein lies one source of difficulty. Pulmonary œdema is so conspicuous in its presence that the observer may overlook dilatation of the right heart which is really making a considerable contribution to disturbances in both external and internal respiration. If the examiner is not skilled in percussion of the heart's borders, cardiac dilatation will be obscured by the emphysematous lung. There is a method of recognizing dilatation of the right heart which may serve better for diagnostic purposes than does percussion for this purpose. This observa-

tion consists in recognizing depression of the arch of the diaphragm in its midportion (*i. e.*, the sternocostal portion of the diaphragm which has its fibers inserted at the costal borders from the midline to as low and as externally as the ninth costal cartilage on the costal margins) and depression of the lateral and posterior portions of the diaphragm which are inserted on the costal margins, below and external to the ninth costal cartilage. In other words, the upper and inner half of the costal margin may be modified in its respiratory excursion by depression of the anterolateral part of the diaphragm, and at the same time the lower and outer part of the costal margin will have its excursions unmodified if the lateral and posterior portions of the diaphragm are not depressed. Enlargement of the heart or enlargement of the heart's sac will cause depression of the anterolateral part of the diaphragm, and enlargement of the lung will cause depression of the entire leaf of the diaphragm.

"These are the problems in phosgene poisoning so far as the diaphragm is concerned, viz., to determine whether the movement of the costal margin during inspiration is modified by flattening of the anterolateral part of the leaf or of the whole leaf of the diaphragm.

"B. Dilatation of the right heart externally to the right sternal border is due to enlargement of the right auricle. In phosgene poisoning we see pulmonary œdema attended by an enlargement of the right ventricle and right auricle without dilatation of the left side of the heart. This will depress the right sternocostal portion of the diaphragm lower than the left sternocostal portion.

"Consequently there will be an asymmetry of inspiratory movement of the costal angle. The upper half of the right costal margin will move less in an outward direction than the upper half of the left costal margin, or (as frequently occurs in dilatation of the right heart) the upper portion of the right costal margin will move toward the median line during inspiration and the entire left costal margin will move in an outward direction. Under these circumstances either digitalin in doses of $\frac{1}{50}$ gr. should be given hypodermically, or strophanthin should be given intramuscularly in doses of $\frac{1}{120}$ gr., either drug to be repeated in two hours until the heart regains its size or the physiologic effect of the drug is demonstrable.

"C. Bronchiolar spasm must be differentiated from pulmonary emphysema. In phosgene poisoning pulmonary emphysema is a very common accompaniment of pulmonary œdema, but the emphysema makes its consequent enlargement of the lung apparent only at the borders where the thin edges of the lungs are sufficiently enlarged to fill the pleural sinuses. The total body of the lung (under these circumstances) is not enough enlarged to depress the total arch of the diaphragm sufficiently to give the diaphragm mastery over the costal margins in its contention against the intercostal muscles for control of the costal margins.

"When bronchiolar spasm, however, does occur, then the entire diaphragm is depressed so that during inspiration there is narrowing of

the subcostal angle and the entire costal margins on both sides are drawn toward the median line during inspiration. From pulmonary œdema or emphysema of phosgene poisoning there is not sufficient depression of the diaphragm to cause inspiratory narrowing of the subcostal angle.

"When this sign of pulmonary enlargement is present, the bronchiolar spasm can be allayed by hypodermic injection of 20 minims of 1 : 1000 of adrenalin. The effect is quite the same as when given for spasmodic bronchiolar asthma. Within two minutes the subcostal angle widens during inspiration and the entire costal margin of each side moves away from the median line during inspiration.

"E. Bronchopneumonia of phosgene poisoning has the same clinical signs and requires the same therapy as bronchopneumonia due to pneumococcus or other infectious organisms.

"F. Cerebral hemorrhages occur in phosgene poisoning and may complicate the picture of mental disturbances, disturbances of consciousness, and also the rate and amplitude of respiration. One patient clearly illustrates this point. The man was gassed on July 29th and came to the C. C. S. with severe blue-gray cyanosis, pulmonary œdema and emphysema, and enlargement of the right auricle to a point midway between the right nipple line and right sternal border. During inspiration the upper and inner half of the right costal margin was drawn toward the median line during inspiration. The lower and outer half of the right costal margin moved outward during inspiration. The entire left costal margin moved away from the median line during inspiration. This showed that there was not sufficient emphysema to be a contributory cause of cyanosis. Digitalin, $\frac{1}{50}$ gr., was given hypodermically, and within an hour the right border of heart dulness was at the right sternal border and the entire length of the two costal borders moved symmetrically outward during inspiration. The blood-pressure, which was 135 systolic and only 40 minimum diastolic before digitalin was given, rose to 160 systolic and 85 diastolic.

"Inhalation of pure oxygen gave him a perfectly normal color, but did not modify the rate or amplitude of respiration, nor did it modify the heart rate or blood-pressure. After three days the patient had a normal color and normal size of the heart, no pulmonary œdema and no emphysema, but the respiratory rate continued in the same rate and amplitude. The temperature was 100° F. There were physical signs of a moderate bronchopneumonia. The patient's mental state did not improve. The pupillary reflexes were normal. The ankle and patellar reflexes were also normal. But there was a pronounced Babinski sign on both sides to plantar irritation. The patient preserved a moderate amount of voluntary muscular power, but there was apparently a marked disturbance in the reciprocal relation of flexor and extensor function of the skeletal muscles and a marked loss of the muscular sense.

"On the fourth day the rectal temperature rose to 105° F., without any change in the other physical signs. Lumbar puncture revealed a diminution of the amount of subarachnoid fluid and no evidence of

hemorrhage into the subarachnoid space. On the fifth day the patient died, and autopsy revealed a normal heart, moderate bronchopneumonia, and many small perivascular hemorrhages about the size of a pinhead confined to the white matter of both hemispheres of the cerebrum and corpus callosum. There were no hemorrhages visible in the gray matter of the brain or in the pons, medulla, or cerebellum. The spinal cord, however, revealed many small hemorrhages in its white substance and none in the gray substance of the cord.

"Clinically, this patient presented a picture which is identical with that of encephalitis hæmorrhagica. The observations indicate that the medical officers should determine how much emphysema, bronchiolar spasm, pulmonary œdema, cardiac dilatation, and bronchopneumonia share in the sources for impairment of the function of external respiration, and they should also be prepared to differentiate between anoxemia and encephalitis hæmorrhagica as sources for disturbances of consciousness.

"Medical officers at C. C. S. should be prepared for the critical use of digitalin and adrenalin as well as oxygen. Cardiac dilatation and bronchiolar spasm in many cases complicate the picture of pulmonary œdema and moderate pulmonary emphysema. The medical officer should also recognize hemorrhagic encephalitis as a cause for modifications of consciousness and disturbed innervation of muscles, otherwise these disturbances may all be ascribed to anoxemia."

In this connection it may not be inappropriate to say a word in regard to the administration of oxygen in cases of poisoning by gases of the type of phosgene. The value of this measure was strongly recommended by Haldane and was adopted by the British and also by the French and Americans. Each nation had its own fashion of administration. I am not conversant with the verdict of the other two countries as to the therapeutic value of its administration in the treatment of gassed cases, but there is no doubt that its use did little to establish a high opinion as to its efficacy among our own surgeons. It was used up to the signing of the Armistice, but much as it is often employed in cases of lobar pneumonia, not expecting any very decided action, but in order that it might be said that no stone had been left unturned to save life. In addition to its use in acute poisoning, Haldane, Barcroft, and Harrison stated in one of the Interallied gas conferences in Paris that good results had been obtained in chronic cases with tachycardia and insomnia by oxygen by the "chamber method." This consisted in keeping the patient in a gas chamber in a 40 per cent. oxygen atmosphere for thirty-six hours or longer.

The two measures of combating the effects of respiratory irritant gases were worked out experimentally by Underhill and others with him in England, and after use in gassed cases the method received the sanction of general medical approval. The experiments which were made to determine the rationality of this form of treatment are quoted in part; that is, in so far as they apply to phosgene, and are very convincing as to the beneficial effect resulting from their use. As a matter

of fact, this method was the one adopted by our own service in treatment of gassed cases and met with approval. It may be contended that the strict compliance with the conditions governing the bleeding and the infusion with isotonic salt solution are difficult to carry out at the front when the stations are clogged by the arrival of numerous casualties. Granting that—and that it is not in every circumstance possible to make the estimation of the hemoglobin index, even by so simple a method as the Tallqvist apparatus—it is still practicable, and at least clinically satisfactory, to use as an index for the procedure the evidence of the condition of the patient, and to take into consideration the time which has elapsed. This forms, according to Underhill, a very important factor in the successful use of either the phlebotomy or the transfusion. Underhill's[2] report covers experiments made also in the case of dogs gassed with chlorin and chlorpicrin, but as it is not practicable to reproduce all of it in this chapter, that quoted is limited to the conclusions reached in regard to phosgene, which, as a matter of fact, is the most important of the three in point of incidence of cases. The findings in the other two are quite as positive as what follows:

"As in the chlorine experiments given above, dogs were gassed in an atmosphere of phosgene for thirty minutes. The concentration was kept at a constant level throughout the gasing by passing the gas mixed with air at a fixed rate through the chamber. Chemical analysis served as a further check upon the concentration during the period of gassing. By this method is obtained a standard gassed animal, and it has been found that the toxicity percentages are certainly accurate within 10 per cent., which covers merely the individual variation of the animals. The following tables give the result of bleeding alone:

TABLE V

"*Effect of Bleeding in Dogs Gassed with Phosgene* (71 to 80 parts per 1,000,000—1 : 14,200 to 1 : 12,500 for thirty minutes).

	Deaths.			Total acute deaths, per cent.	Delayed deaths, per cent.	Survivals, per cent.	Animals used.
	24 hours, per cent.	Second day, per cent.	Third day, per cent.				
Untreated	38	21	10	69	10	21	20
Bled one hour after gassing	27	15	..	40	10	50	30
Bled five hours after gassing	33	10	..	43	10	47	30

Discussion of Table V

"The above figures show that one bleeding to the extent of 1 per cent. of the body weight, either one hour or five hours after gassing, produces equally good results with concentration causing 79 per cent. mortality in untreated animals. The acute deaths are reduced from 69 per cent. in untreated animals to 50 per cent. in the treated. These figures are sufficiently significant to show that in dogs gassed with phosgene bleeding has a positive beneficial effect.

Effect of Bleeding and Infusion.—"Inasmuch as a combination of bleeding followed by an infusion of isotonic sodium chlorid solution gave better results in the treatment of animals gassed with chlorin, the same procedure was applied to dogs gassed with phosgene. The following table gives the result of this method of treatment. Both the bleeding and the infusion were performed one hour after gassing:

TABLE VII

"*Effect of Bleeding and Early Infusion in Dogs Gassed with Phosgene* (71 to 80 parts per 1,000,000—1 : 14,200 to 1 : 12,500 for thirty minutes).

	Deaths.						
	24 hours, per cent.	Second day, per cent.	Third day, per cent.	Total acute deaths, per cent.	Delayed deaths, per cent.	Survivals, per cent.	Animals used.
Untreated	30	21	10	69	10	21	29
Treated	40	3	3	50	3	47	30

Discussion of Table VII

"Bleeding one hour after gassing, to the extent of 1 per cent. of the body weight, followed by immediate infusion of an equal quantity of isotonic sodium chlorid solution, yielded results in the first twenty-four hours less satisfactory than bleeding alone. This led to the experimentation described below which has yielded a course of treatment more successful than any hitherto obtained. It is of interest to note that of the 50 per cent. of the animals surviving the acute period, but 3 per cent. die subsequently, as against 10 per cent. of the untreated animals.

Bleeding and Delayed Infusion.—"It is well known that immediately after gassing with chlorin there is a concentration of the blood. Upon investigation of dogs gassed with phosgene it was found that in the first four hours after gassing the blood has a distinct tendency to be more dilute than normal, but later, depending on the severity of the gassing, the blood becomes concentrated. At a concentration of 70 to 80 parts per 1,000,000 this concentration occurs about the eighteenth hour after gassing. Above 80 parts per 1,000,000 the blood becomes thick sooner—about fifteen hours after gassing. On the basis of this result it was decided to test the value of bleeding 1 per cent. of the body weight one hour after gassing, and to delay infusion until fifteen to twenty hours after gassing. The results are tabulated below in two ways: First, for total number of animals treated by bleeding and infusion, including those animals which died before the infusion, as compared with animals not treated and with another group treated by bleeding only; second, in each group a percentage of animals, equivalent to those which died before infusion, is eliminated. This is done to determine whether infusion increases the expectation of survival.

TABLE VIII

"Effect of Bleeding and Delayed Infusion in Dogs Gassed with Phosgene (71 to 80 parts per 1,000,000—1 : 14,200 to 1 : 12,500 for thirty minutes).

	Deaths.						
	24 hours, per cent.	Second day, per cent.	Third day, per cent.	Total acute deaths, per cent.	Delayed deaths, per cent.	Survivals, per cent.	Animals used.
Untreated	38	21	10	69	10	21	29
Bleeding only	27	13	..	40	10	50	30
Bleeding and delayed infusion	14* ..†	14	3	31	17	52	35
14 per cent. early deaths eliminated from each group.							
Untreated	28	24	12	64	12	24	25
Bleeding only	15	15	..	31	11	58	26
Bleeding and delayed infusion	..	17	3	20	20	60	30

Discussion of Table VIII

"The method of treatment adopted herewith—bleeding in one hour to the extent of 1 per cent. of the body weight followed by the infusion of isotonic sodium chlorid solution fifteen to twenty hours after gassing—yielded the following results: Considering the first grouping, during the most critical period, namely, the first twenty-four hours, the deaths are decreased from 38 per cent. in the untreated animals to 14 per cent. in the treated animals. It is also evident that infusion has added to the value of bleeding, for in this same period the deaths with bleeding alone amount to 27 per cent. as against 14 per cent. when animals are also infused. From this it is clearly indicated that infusion has a beneficial effect during the very acute period. Now passing to our second classification, where a number of animals equivalent to those which died before infusion are eliminated from the three groups, further evidence of the immediate value of infusion is indicated by the fact that, whereas 15 per cent. of the animals die in the first twenty-four hours when bled only, none of the animals which are infused die in this period. By this method of grouping a preliminary idea of the postacute value of infusion may also be obtained. Here it is evident that the total number of acute deaths has been reduced from 64 per cent. in the untreated to 31 per cent. when bled only; to 20 per cent. when bled and infused with isotonic salt solution after fifteen to twenty hours. This is further evidence that infusion is of value during the whole acute stage. The total recoveries are, of course, of the same order in bleeding alone and bleeding and infusion in these experiments, but we shall show in subsequent tables how this lead is developed and the evidence strengthened to prove the value of infusion. There can be no doubt that so far the life of the animals which die is considerably lengthened.

Bleeding and Delayed Infusion in Animals Gassed at a Higher Concentration of Phosgene.—"One thing stands out in phosgene poisoning, namely, that, in general, the higher the concentration of gas to which an animal is subjected, the sooner the toxic symptoms appear; that is, the more rapid is the onset of acute death. It is also found that

*Before infusion. †After infusion.

the concentration of the blood appears earlier at these higher concentrations. Therefore, theoretically, infusion for the purpose of diluting the blood should be performed earlier. The following data give the result of bleeding one hour after gassing at concentrations of 80 to 90 parts of phosgene per 1,000,000 parts of air, followed by infusion ten hours after gassing. Here also the data are grouped in two ways as above.

TABLE IX

"*Effect of Bleeding and Delayed Infusion in Dogs Gassed with Phosgene at Higher Concentrations* (80 to 90 parts per 1,000,000—1 : 12,500 to 1 : 11,100 for thirty minutes).

	Deaths.			Total acute deaths, per cent.	Delayed deaths, per cent.	Survivals, per cent.	Animals used.
	24 hours, per cent.	Second day, per cent.	Third day, per cent.				
Untreated	54	10	3	67	13	20	30
Bleeding and delayed infusion	23* 14†	14	3	54	6	40	35
23 per cent. early deaths eliminated from each group.							
Untreated	39	13	4	57	17	26	23
Bleeding and delayed infusion	19	19	3	41	7	52	27

Discussion of Table IX

"Here again the general features of Table VIII are repeated. There is an undoubted reduction of the acute deaths, especially in the early period.

Bleeding and Infusion at the Proper Time as Indicated by Hemoglobin Determination.—"The general thesis that infusion should be resorted to when the blood shows a tendency to thicken has now been followed to a logical conclusion. It is found that simple hemoglobin determination (the Tallqvist hemoglobinometer is sufficiently accurate) can be used as an index of this concentration. A group of animals has therefore been gassed at a concentration of 80 to 90 parts of phosgene per 1,000,000 parts of air, and bled one hour after gassing. As the blood showed concentration, infusion was resorted to and repeated as required. The initial infusion should not be delayed in any case until the blood has reached a concentration more than 25 per cent. above normal. A second infusion is indicated when the hemoglobin shows a concentration of 40 per cent. above normal. The treatment should not be repeated too frequently. At this stage, as long as the concentration of the blood does not increase, further infusion is not necessary. The table on page 885 gives the preliminary results of this method of treatment, compared with the simple mass treatment at the same concentration.

* Before infusion. † After infusion.

TABLE X

"Effect of Bleeding and Infusion at the Proper Time as Indicated by Hemoglobin Determination in Dogs Gassed with Phosgene (80 to 90 parts per 1,000,000—1 : 12,500 to 1 : 11,100 for thirty minutes).

25 early deaths eliminated from first two groups.*

	Deaths.			Total acute deaths, per cent.	Delayed deaths, per cent.	Survivals, per cent.	Animals used.
	24 hours, per cent.	Second day, per cent.	Third day, per cent.				
Untreated	39	15	4	57	17	26	23
Bleeding and delayed infusion.	19	19	3	41	7	52	27
Bleeding and infusion at proper time	..	..	..	22	5	73	22

Discussion of Table X

"This table shows conclusively that when the concentration of the blood is followed by the hemoglobin count, and when the time of infusion is properly ascertained, in addition to the great reduction of acute deaths heretofore demonstrated, the percentage of total recoveries is markedly increased—from 26 per cent. in the untreated group to 52 per cent. in the group where the time of infusion *was not* accurately correlated with blood concentration (infusion usually being about ten hours after gassing), and to 73 per cent. when the time of infusion *was* properly ascertained. In the communication from which these data are taken it is pointed out that but one delayed death occurred. This may mean that the treatment has a tendency to prevent secondary infection, a significant point when dogs are the experimental animals.

Discussion of Bleeding as a Method of Treatment for Poisoning with Chlorin, Chlorpicrin, and Phosgene.—"It has been conclusively demonstrated for three typical examples of respiratory irritants that bleeding has a beneficial effect. It seems permissible, therefore, to assume that this method of treatment might permit general application in counteracting the effect of gases whose chief symptoms are edema and congestion of the lungs. As a preliminary recommendation for man, we would suggest that early bleeding be performed when possible, especially in severely gassed cases.

Discussion of Intravenous Infusion of Isotonic Salt Solution as an Accessory to Bleeding.—"On the basis of results obtained in both chlorin and phosgene poisoning, infusion of isotonic salt solution at the period when the blood concentrates gives better results than simple bleeding. The value of the accessory infusion of isotonic salt solution is true beyond doubt in dogs gassed with lethal concentrations of phosgene, bled one hour after the gassing, and infused as hemoglobin determination of the individual animal indicated concentration of the blood.

"In addition to the experiments given above, we wish to present here

* At this writing we are uncertain whether in this compilation early deaths were eliminated. Hence we present the data as if this were the case, and thus put them in the worst possible light.

very briefly the results of an investigation which bears directly on the question of infusion. A series of dogs was exposed to graded concentrations ranging from 4 to 50; 51 to 60; 61 to 70, and 71 to 80 parts of phosgene per 1,000,000 parts of air.

"The length of this exposure was thirty minutes; 20 dogs were gassed at each of these concentrations of phosgene. As indicated by the hemoglobin and total solid determinations (these give parallel curves), it was found that the concentration of the blood is an index of the severity of the gassing. Furthermore, the animals that died acutely have, invariably, a blood concentration curve which tends to assume a vertical course.

"Hence, we must conclude that concentration of the blood is contributory to a fatal outcome. Treatment for this condition is most certainly indicated. Intravenous infusion of isotonic salt solution into experimental animals at this stage has been definitely shown to increase the chance of recovery.

Conclusions.—"1. Bleeding is beneficial to animals gassed with any of the three typical examples of the class of respiratory irritants—chlorin, chlorpicrin, or phosgene.

"2. Bleeding, followed by accessory infusion of isotonic salt solution at a time when, by hemoglobin determination, the blood is shown to be concentrating, and a repetition of this process at well-timed intervals, increases the chances of recovery.

"3. In so far as animal experiments may indicate, general application of these procedures to gassed men seems justifiable."

Chlorin

This is a liquid under relatively low pressure at ordinary temperature and has a density of 2.45. It was used as a drift gas and was mixed with phosgene for the same purpose since it increased the gas pressure of the latter. It is irrespirable and a 0.05 per cent. strength is fatal. Its primary importance as a weapon passed on the adoption of phosgene except as it was used in conjunction with the latter as mentioned.

The symptoms and pathology of poisoning by it depend on the concentration which is employed. High concentrations are almost immediately fatal, while the patients who survive after being gassed by lesser concentrations develop very intense pulmonary edema, extreme cyanosis and dyspnea, and frothy expectoration. The rapid and distressing edema of the lungs is a marked feature and those who die in this stage are literally drowned in their own fluids. Death is by asphyxia. The right side of the heart is dilated as in phosgene poisoning, and there is also emphysema, intervesicular, mediastinal, and subcutaneous. The abdominal organs show marked passive congestion and there are hemorrhages in the heart, both sub- and endocardial, and submucous in the stomach. Bacterial invasion of the lungs is common after the stage of edema disappears, and bronchitis, mucopurulent in type, may develop.

Hill holds that the edema is due to injury to the surface epithelium,

while Shaefer believes that it is due to obstruction of the pulmonary vessels.

The gastro-intestinal symptoms are marked. There is pain, epigastric in character, and vomiting which may be bloody and which is not uncommonly one of the early manifestations. Gastric ulcer as a resultant from this is a not infrequent sequel in cases which recover.

The changes in the kidney are not marked and few cases show albuminuria. Miliary hemorrhages have been described, but they are not so common as in cases of poisoning by phosgene, and from the fact that many of those reported were due to wave gas it is open to question as to whether the active agent was chlorin by itself or in combination with phosgene. The miliary hemorrhage is a well-marked symptom with the latter gas, as has been already stated.

The treatment of this form of poisoning is the same as that in phosgene, and the series of experiments reported by Underhill, and quoted previously, give the rationale of this.

Before leaving these two substances, chlorin and phosgene, it may be well to call attention to some confusion which has existed in regard to the nomenclature. For some reason which is not apparent monochlormethylchloroformate, or "palite," has been referred to as "phosgene." Norris is guilty of this, and the same confusion has existed with others. Trichlormethylchloroformate has also been commonly referred to as "diphosgene." There is no relationship between them, but Warthin suggests that the fact that the formula for "diphosgene" being $C_2O_2Cl_4$, as against $COCl_2$ for phosgene, this mistaken nomenclature may have arisen from this fact. In dealing with the military nomenclature of the gases this may give rise to some confusion unless the facts are borne in mind.

Chlorpicrin

This gas was first used by the Germans with the idea of penetrating the mask of the Allies, it being the idea that this being accomplished, it would necessitate the removal of the mask and the subsequent gassing of the men either by this gas or another used in conjunction with it. The fact that chlorpicrin is an active gas in producing vomiting lent weight to this plan, but, as a matter of fact, it did not in this way meet the measure of success which was expected, and the further fact that the German mask was found to be penetrated by it more readily than either the British or the French made it rather a boomerang. In addition to the nauseating effect and the irritation produced by it of the ocular and respiratory mucosæ it has pronounced lethal effects, being necrotic in this action and inducing death through pulmonary edema and asphyxia. The treatment for it is analogous to that for both the other pulmonary irritant gases described, chlorin and phosgene. It was used in combination with phosgene and also with "diphosgene" as well as with stannic chlorid.

Death from its effects is usually within forty-eight hours in the fatal cases, and those who have been once gassed have a much greater susceptibility to the effect of the gas than those who have not. The minimum

unbearable concentration with mouth breathing and eyes protected was found by Makins to be between 1 to 160,000 and 1 to 16,000. The lower concentrations are usually detected by some effect on the throat rather than by that on the mouth or lower respiratory tract. The chief symptom is coughing, which may or may not be preceded by a tickling or burning sensation. The changes found at autopsy are similar in many respects to those which show in poisoning by chlorin or phosgene or any of the group of pulmonary irritants.

In regard to treatment, what has already been quoted from Underhill's report as to the efficacy of bleeding and infusion of isotonic salt solution in relation to phosgene, is equally applicable to chlorpicrin, as he states.

MUSTARD GAS

Although not to be considered in the same category as phosgene, chlorin, diphosgene, chlorpicrin, and gases of similar characteristics, so far as lethal effect is concerned, there can be no doubt that of all those which were used in the war dichlorethylsulphid was far and away the most important, the most universally employed, and the one which probably would have done more from the standpoint of gas warfare to decide the issue if hostilities had not ceased on November 11, 1918. Used first by the Germans, the Allied nations were not slow to appreciate its advantages, and as soon as satisfactory arrangements could be made for its production in quantity the resources of Great Britain, France, and the United States were turned earnestly to its production. In this country the output at Edgewood Arsenal at the time of the Armistice was well up to 30 tons a day, and there was practical assurance of a rapid increase up to 100 tons daily. It has many features which commend themselves for a weapon of this sort. It is toxic in concentrations which cannot be detected by the sense of smell. It penetrates all clothing (even "gas-proof" clothing in time) and affects the skin as well as the mucosæ. It is painless in its action on the skin and may not be detected in this way. Its action is delayed and it is remarkably persistent on the terrain on which it has been scattered. All these factors tend to make it a weapon which has an effect on the *morale* as well as on the physical body itself. It has the further advantage of being so heavy a body that it can be used with high explosives without being dissipated by the explosion, as were the lighter gases. It was not a gas, truly speaking, but a liquid which was slowly vaporized, and acted either as a liquid or a gas.

It is not a new product, but was first made and described by Victor Mayer in 1886. It served no extended purpose until it was utilized as a weapon of offence by the Germans in 1915. It is, in its pure state, a colorless, heavy, oily fluid, heavier than water and not miscible with it. It has a faint odor which has been likened to mustard, and its boiling-point is 217° C. While the pure product is colorless, that in commercial use, if we may so denominate use in war, was of shades of brown from a light tinge to a color nearly as dark as iodin or bromin, the color being

due to impurities which did not affect its efficiency. On analysis it shows the following composition:

Dichlorethylsulphid	68.2
Carbon tetrachlorid	15.2
Residue	12.4
Hydrocyanic acid	trace

The function of the carbon tetrachlorid is to lower the freezing-point of the dichlorethylsulphid, which melts at 12° C., carbon tetrachlorid, chloroform, dichlormethylether, and chlorobenzene were used for the purpose of lowering the freezing-point of the gas, or to act as vaporizers. After the discovery of the gas Mayer carried on some experiments with it, and from its effect on animals determined that its most severe effects were manifested only after its entry into the blood. On account of its effect on those who conducted the experiments further investigation of it was discontinued, and from this time up to its intro-

FIG. 646.—MUSTARD GAS. SHOWING BLISTERED BLEBS. (Reproduced by permission of the Chemical Warfare Service, U. S. Army.)

duction as an agent of war in 1915 it seems not to have attracted much attention in either chemistry or medicine. Its very prominent place in chemical warfare, however, revivified interest in it, and the studies which Mayer had dropped in 1887 were taken up and carried through with a view to determining both the action of the poison and any measures which might be taken to combat it.

A description of the onset given by Clarence J. West[3] is as follows: The general effects of this substance, without protection, are: "Conjunctivitis, soreness of throat, and hoarseness. Gradual necrosis of mucous membrane of the air passages, leading to bronchitis. Later the bronchitis becomes purulent, extends to the air sacs, causing bronchopneumonia, terminating in death. In addition, there are wide-spread burns on the skin, affecting chiefly the covered parts of the body, such as the front of the chest, the axillæ, the inside of the elbows and forearms, the thighs, and the genitals (Figs. 646, 647). Nevertheless, the

face, hands, and scalp may also exhibit burns. In order of development there is first observed an erythema, with some irritation, but no pain. This is followed by the formation of blisters, accompanied, in the genitals, by much swelling and œdema. The erythema is attended by diapedesis of blood-cells. Even when no blisters are formed there may be dark purple patches, the color of which does not entirely disappear on pressure. These give place to dark brown pigmented areas. After a week or so there is wide-spread desquamation of the superficial epidermis (as in scarlet fever), leaving pigmented skin below. The whole process is very slow and, apart from infection, painless. The blisters may take from two to four days to develop and the process of healing may take some weeks.

"These effects may certainly be produced by a prolonged exposure to concentrations of 1 to 100,000. Fine spray from exploding shells or

Fig. 647.—Mustard Gas. Burn of Hand and Wrist, Later Stage. Note Resemblance to *x*-Ray Burn. (Reproduced by permission of the Chemical Warfare Service, U. S. Army.)

contaminated earth may soil the clothes, the substance is then slowly volatilized, aided by the warmth of the body, and affects chiefly the warmer parts and those covered by thin skin. The extent of the infection of the lungs is generally proportional to that of the conjunctivæ. Both may make their appearance as late as the third day after exposure."

Gilchrist gives the following history of a severe and unprotected case: "On exposure to the vapor or spray of the substance nothing is noticed at first save the faint, though characteristic odor. After the lapse of two to three hours the eyes begin to smart and water, and they are soon reddened with an acute conjunctivitis. The nose runs; there may be sneezing. Nausea, retching and vomiting, associated with epigastric pains commence at the same time as the pain in the eyes, and they recur in attacks at frequent intervals for several hours. Later the throat feels dry and burning, the voice becomes hoarse, and a dry harsh cough develops.

"Inflammation of the skin now shows itself in a dusky red erythema of the face and neck, which looks as though they had been scorched, and are almost painless, while the inner surfaces of the thighs, genitals, and sheltered parts of the body are similarly affected. This is rapidly followed by the development of small blister blebs in the same areas.

"At the end of twenty-four hours a typical appearance is presented. The main distress is caused by the pain in the eyes, which may be very great. The patient lies virtually blinded, with tears oozing between bulging, œdematous eyelids over his reddened and slightly blistered face, while there is a constant nasal discharge and an occasional aphonic cough. The respiration is fairly normal, both in rate and depth. There may be frontal headache, associated with pain in the eyes, and the photophobia with blepharospasm is always a marked symptom. Death practically never occurs in the first twenty-four hours.

"During the second day the condition is aggravated by the development of the vesicles into large blisters over the erythematous areas, while the scrotum and penis become œdematous and painful. Bronchitis now sets in with abundant expectoration of mucous in which there may be found large sloughs from the inflamed tracheal lining. The temperature, pulse-rate, and respiration rate are all increased, and secondary infections of the necrotic mucous membrane in the respiratory tract soon lead to the development of a bronchopneumonia with slight cyanosis, cardiac dilatation, and death at any rate from the second or third day to the third or fourth week in the more lingering cases."

One of the reasons for the effectiveness of mustard gas is its faculty for damage in low concentrations and the difficulty in detecting them. The low concentration of 1 part in 100,000 acting for twenty minutes produces as much effect as the high concentration of 1 part in 10,000 acting for two minutes. It is understandable that a man might remain in the lower concentration for the length of time given without being conscious that he was in danger, being without the warning which he would have in the higher percentage. In regard to the concentrations necessary to produce death, the following table gives them for some of the strengths:

Gas.	Exposure for five minutes.		Exposure for twenty minutes.		Exposure for two hours.	
	Concentration by volume.	Gm. per M³.*	Concentration by volume.	Gm. per M³.	Concentration by volume.	Gm. per M³.
Mustard gas.....	1 per 13,000..	0.5	1 per 100,000.	0.07	1 per 300,000.	0.02

It was not only the universality of the infection which resulted from exposure to this gas which made it so grave a weapon in offence, but the fact that although it was not so seriously toxic in its effects as some of the other gases used, it was very certain in its action of incapacitating

* Grams per cubic meter.

men, and that this incapacity was serious enough and of sufficinet duration of time not only to deplete the number of fighting effectives, but also to work the additional hardship on the enemy of leaving him with a number of men on his hands who not only could not be counted in his fighting force, but must be maintained and cared for. It was the imposing on him of a large number of wounded with the consequent drain of economic power. Just what the extent of this was may be seen in the figures in a report made from the A. E. F. in the latter part of 1917.

This says that all men have eyes affected, and that at least 95 per cent. have throat and lungs affected; 70 per cent. have skin burns, and 33 per cent. have heart trouble. No deaths are known to have occurred under twenty-four hours. In six weeks all skin affections are cured, but only 60 per cent. of the eyes and lungs, and 9 per cent. of the heart affections. Prolonged exposure to weak concentrations of the gas causes laryngitis, accompanied by loss of the voice, which though apparently not serious, is sufficient to put men temporarily out of action. It is stated on good authority that the average time that casualties will remain away from service is three months. Men returning from convalescence are, in general, very much weakened and therefore have to be spared as much as possible. There are numerous cases where evacuation has been necessary after return to the unit. One should count on 20 per cent. of those evacuated who, after an absence of two and a half to three months, have not rejoined their units.

In the beginning of its use, before its nature and effects were understood, it might have been an almost irresistible agent if it had been used in the profusion which was to mark the latter months of the war. When first employed against the British in July, 1917 it had all the advantage of a new weapon, and was in effect a surprise, although it is to be admitted that at that time all forces were accustomed to gas attack and habituated to protection against any of the usual forms of assault by this form of weapon.

In its action mustard gas is a vesicant and escharotic, and the lesions caused by it may be divided into those which affect the skin, the eyes, and the respiratory system.

The latter are more often conducive to a fatal issue than the former, though they are usually present in the same degree or, rather, it should be said, those exhibiting serious respiratory lesions are apt to evidence the others also. The skin lesions, if pronounced, may, of course, take on as serious a character as would any other burn involving a considerable extent of body surface and subject to an equal infection with attendant absorption. The respiratory symptoms are general in their incidence. It is probably a fair statement that 95 per cent. of those affected by this gas show respiratory involvement. This is evidenced in statistics as to injuries from this cause quoted from the report from the A. E. F.

The action on the lungs and air passages, so far as a fatal termination is concerned, is not dependent on the primary action of the gas, as in the case of phosgene and chlorin, but to a secondary condition set

Fig. 648.—Mustard Contact Burns of Left Shoulder, Showing Healing. (Reproduced by permission of the Army Medical Museum, Washington, D. C.)

up after the initial lesion by the mustard gas. There is a certain amount of trauma of the tissues, but it is not due to this that death supervenes, but to the following condition of bronchopneumonia. Here again we have the insidious action of the agent. Slow to be recognized, slow in its action on the ocular conjunctiva, delayed in its effect on the skin, its worst damage is not fulminating, as in the case of the lung irritants, but comes on slowly and by means of a secondary process which it lights up. There is little wonder that it was the most feared of the different measures employed in chemical warfare.

The exact mechanism of the effect of this poison on the body is not as yet definitely determined. It has been suggested, with very reasonable basis of confirmation, that it is due to the liberation of hydrochloric acid in the cells, this being due to hydrolysis and the breaking up of the compound into hydrochloric acid and another body, probably dihydroxyethyl sulphid, which may be again converted into mustard gas by boiling with hydrochloric acid. The hydroxy compound is in itself inert and cannot be the cause of the symptoms of the poisoning. Many of the symptoms which are produced by dichlorethylsulphid are paralled by hydrochloric acid, and it is possible that the effect of this compound on the system is to be accounted for in this way, although Warthin, among others, is doubtful whether the causation is as simple as this theory makes it.

As has been stated, this product is in either a liquid or a gaseous form, and is, in low concentrations, an escharotic to the animal tissue with which it comes in contact. The degree of injury is increased by height of concentration, length of time of exposure, the susceptibility of the individual, and upon certain other factors, such as warmth, moisture, and pressure—as of the clothes on certain parts. It is evident that the parts soonest to be affected will be those where the skin is thin and abundantly supplied with hair and sweat-glands, such as the crotch and the axilla. The progress of the lesion is an erythema, vesication, scar formation, sloughing and tardy resolution, not infrequently accompanied with pigmentation of the parts. Exposure to low concentrations for more or less prolonged periods may give rise to skin lesions which, in accordance with the location, may simulate itch or venereal sores. Injuries of this degree are accompanied by itching, as in eczema, and the so-called "Nikolsky's" sign is the formation of a blister soon after scratching the affected part. The burns, after development, are painful and the more severe are very slow in healing; much as are the burns from the *x*-rays (Fig. 648). The parts affected after healing are more susceptible to injury than before, and this applies to injuries in general and not merely to the action of dichlorethylsulphid. The cornea is peculiarly susceptible to the action of the gas, and this action begins as early as ten to fifteen minutes after exposure to dilute concentrations. There develops a more or less severe catarrhal or even purulent conjunctivitis, and this involves both the ocular and the palpebral membranes, with much consequent swelling. The cornea becomes gray or hazy, loses its luster, and shows a reduced or blurred "window reflex."

The upper part of the cornea, being protected by the lid, is usually comparatively clear. In severe cases due to cicatrization there may be impairment or even loss of vision. The recovered cases show an increased sensitiveness to irritants such as light and dust.

The action on the respiratory tract lessens in intensity from the upper air passages downward. It is a local damage to the epithelial

Fig. 649.—Mustard Gas. Tongue, Fauces, and Larynx.
Ulceration at base of tongue and on wall of larynx. (Reproduced by permission of the Army Medical Museum.)

membrane and may range in severity from a catarrhal to a purulent condition. It takes the appropriate nomenclature, as it occurs in the nose, mouth, pharynx, trachea, larynx, or bronchi. The lesions at the base of the tongue and in the larynx are apt to be the most severe and it is not infrequent to find tracheal ulcerations (Fig. 649).

Atelectasis, emphysema, and pulmonary edema may develop, and as a secondary process a purulent bronchopneumonia may be set up, as stated previously. It is very probable that the injuries may predispose to later development of tuberculosis, and it has been suggested that the formation of scar tissue from the burns may give rise hereafter to carcinoma of the affected regions, although it is as yet too early to have witnessed any such sequels.

There may be injuries to the stomach due to swallowing the gas or saliva contaminated by it, and this may vary from a catarrhal condition to gastric ulcer.

There are no changes in the blood or urine which are attributable solely to the effect of the poison. In severe burns of the skin there may be a secondary anemia or a picture of severe toxemia, while the urine shows albumin and casts.

There is no evidence that there is any systemic action of the poison, and there is no metastasis from the point of infection.

As a matter of fact, there is less of interest in the pathology in these cases than in the symptomatology.

As in all forms of poisoning by gas, the treatment of that caused by dichlorethylsulphid is by far more important from the standpoint of prophylaxis than in the care of the lesions themselves after they have been acquired. In spite of extended research and repeated experiment nothing has been found which will obviate the occurrence of a burn of the skin, except possibly the immediate removal of the liquid by mechanical means.

Many remedies have been tried out for this purpose, some of which are as follows (reported by British investigators) no data being given as to methods used, nor control of results):

Useless: Sodium bicarbonate, ammonia, hydrogen peroxid, bleaching powder, formaldehyd, hexemethylenetetramin, sodium bisulphite.

Harmful: Iodin.

Doubtful: Benzaldehyd.

Some benefit: Carron oil, potassium permanganate, chloramin-T, aqueous silver nitrate (5 per cent.). Dichloramin-T in chlorcosane has given fairly good results according to the reports of Amberg, Austin, and Helmholtz. Magnesium sulfate has little curative power, nor have mild alkaline solutions or poultices of green soap. The same may be said of zinc oxid, ammoniated mercury, linseed oil, zinc stearate in vegetable oil.

Gilchrist gives the following general recommendations in regard to treatment:

Treatment of the Eyes.—Wash the conjunctiva with a solution of bicarbonate of soda (1 per cent. strength) and then treat with a little sterile oil. In washing the eyes use a syringe or douche cup, opening the eyelids wide, inverting them if possible, and paying attention particularly to the condition of the cornea. This treatment should be administered several times daily. In milder cases the most troublesome feature is usually the photophobia resulting from burns of the

eyes, and the only treatment in these cases is protection against the light.

Treatment of Mucous Membranes.—The nasal and pharyngeal mucous membranes should be thoroughly cleaned with bicarbonate of soda solution. In severe cases with persistent cough due to ulcers of the trachea the condition is best treated with steam inhalations and cough mixtures.

Gastro-intestinal Complications.—Regulation of the diet is of the utmost importance: a milk diet, or, if necessary, a plain water diet. The internal administration of bicarbonate of soda is often beneficial. Marshal finds that this should be given as early as possible.

Respiratory Symptoms.—Eucalyptus inhalations and fumigations should be used early, relieving the patients and acting as antiseptics. They appear to prevent secondary infections of the respiratory system.

Warthin strongly recommends for the burns the use of Dakin's solution of a strength, where possible, without too much discomfort, of 0.5 per cent. of hypochlorous acid. This is to be used as a full bath if the injuries are extensive, otherwise as a sitz or local bath. Where the wet treatment, which he considers the preferable method, is not carried out, his choice is either dichloramin-T in chlorcosane or chloramin-T in sodium stearate. The Dakin may be alternated with hypertonic salt and physiologic salt, three hours for each, this treatment to be continued during the daytime and at night substituting a vanishing cream liberating hypochlorous acid or chlorazene. He does not favor the use of silver nitrate, iodin, or permanganate of potassium, and also finds that magnesium sulphate is without benefit.

Most writers condemn the use of ointments and dressings with an oily base. There is not the same ground for their employment as in thermal burns, since the element of pain is not as marked, and the damming up of possibly infective matter in this way may lead to further damage. Warthin recommends dichloramin-T in 0.5 per cent. solution in the ocular lesions, and either a weak Dakin or a 25 or 50 per cent. solution of chlorcosane as a spray or gargle in the throat conditions.

From the time of the exposure liquids should be given in increased quantity to dilute the urine and lessen the chance of damage to the kidney. Digitalis is of benefit for this condition also, and if, as is not unusually the case, there is rapid heart action with possible ventricular dilatation, it is indicated on that account also. The use of the colloidal silver preparations as well as cocain in the ocular troubles is not considered advisable.

Inasmuch as there is nothing to indicate that there is any general toxic action from dichlorethylsulphid the treatment of the conditions which arise as a result of damage to the skin, respiratory tract, and secondary infection, or decubitus with a resulting absorption will be treated as is usual in such conditions.

There is little doubt that those who have been gassed with mustard must count on an increased susceptibility to diphtheria, pneumonia, and allied bronchial and pulmonary diseases, and should take corre-

sponding precautions. Their expectation of life has undoubtedly been lessened.

It would seem, then, that the treatment for this peculiarly insidious poison is almost entirely symptomatic, that there is no specific line to be followed, and that, in effect, the treatment is directed against the things which it may give rise to rather than to the direct effects of the poison itself. It is possible, in regard to burns of the skin themselves, that if the theory of the production of the lesions is demonstrable as being the liberation of hydrochloric acid within the cells, as suggested, a method of intracellular alkaline therapy may be worked out to counteract this effect.

West reports a series of experiments along this line in which the amines were tried out on experimental skin burns in man. It was found that the following were irritating to the human skin: N-butylamin, amylamin, hexylamin, heptylamin, and ethylenediamin; and the experiments, so far as they were concluded, seemed to show better prospects for those named than the simple amines which were also tried. The experiments were not, however, completed sufficiently to form the basis for more than a suggestion that there might be something along this line in the possibility of a more certain arrest of the escharotic effect of this gas.

As has been stated on a preceding page, prevention is of infinitely more value as regards the gas than any curative measure, and a very sensible epitome of the rational measures to be taken to avoid infection by it is set forth in the following set of factory rules which appeared in a report by Clarence J. West to the Chemical Warfare Section. The prevention of infection of an army in the field is covered, in general terms, by the wearing of the respirator, of special gas-proof clothing, by the disinfection of arms and equipment contaminated by the liquid, the neutralization of ground infected by it, and the protection of food from contact with it.

Suggestions for Factory Protection.—Mustard vapor in low concentrations causes conjunctivitis, or irritation of the eyes. Long exposure to the gas will cause blindness or injury to the vision.

Increase the ventilation and require the wearing of goggles; prevent leaks and destroy spilled mustard with bleach.

Mustard vapor in medium concentrations will cause severe conjunctivitis with bronchitis, laryngitis, loss of voice, and diffuse areas of erythema.

Men should not be allowed in it without proper protection. Mustard in higher concentrations is rapidly felt in the eyes, produces intense burns of the thin skinned portions of the body, particularly about the crotch, axilla, and back, in from one to two hours.

If breathed it results in an intense destruction of the lining of the upper air passages with pneumonia usually following. Violent nausea, vomiting, and shock frequently follow severe exposures. No treatment known can save a man who has been burned over a sufficiently large area.

No man should be allowed in such an atmosphere without complete

protection. This may be given for short periods by coverall suits, masks, thick rubber gloves, and rubber boots. For long periods the air line helmet and coverall suit, gloves, and boots should be worn; an air line and compressor is required with this outfit. Rubber aprons or canvas impregnated with beeswax and soft paraffin should be worn under ordinary conditions. Gloves dusted on the inside with starch or zinc carbonate or magnesium carbonate and impregnated with beeswax and soft paraffin give good protection. They should be plunged in dry bleach frequently to destroy any mustard.

Liquid mustard on the skin causes intense blistering, necrosis, and slow-healing burns. It may be removed completely by scrubbing with kerosene, followed by soap and water. If this is done in time no harm results. After the burn has formed nothing has been found that will greatly shorten the sluggish healing. On the clothes a spill of liquid mustard quickly penetrates and will cause severe burns underneath.

Remove the clothing at once and sponge off the body with kerosene, soap and water, and put on fresh clothes. Clothing may be cleaned from mustard by long soaking in warm water or soapsuds and allowing to hang in the open air until absolutely free from odor. Clothing, leather gloves, and shoes may also be cleansed by soaking thoroughly in kerosene or gasoline and then allowing to dry. Care must be taken not to let the gasoline accumulate too much mustard before it is changed. It may, however, be used later for purposes of combustion.

Bleaching powder should be used freely about the plant, sprinkled on the floors where any mustard has been spilled, and kept in convenient receptacles for use on gloves and boots. A medical officer should be in charge of the health of operatives. All eye disorders, throat and lung complaints, and burns should be taken to him for examination and treatment *at once.* Operatives should be encouraged to report and should not be encouraged to treat themselves. They should not be allowed to eat their lunches in the factory. They should be supplied with ventilated lockers, and required to change from their street clothing to clothing worn only at the plant. At the end of a shift operatives should be required to take a shower-bath, changing again to their street clothes. Aprons, coverall suits, gloves, and boots should be assigned to each man. They should be inspected daily and, where mustard is suspected, sent to the renovating department and cleansed.

Some individuals are very sensitive to mustard. Such men should not be allowed where they can come in contact with it. They are constantly on the casualty list. Repeated burns from mustard appear to increase a man's sensitiveness to the vapor. Badly burned men should be detailed to some other type of service.

A competent physician should be responsible for the treatment of mustard casualties. Amateur treatment of these casualties has been found to be extremely dangerous and should not be resorted to under any circumstances.

Prevention is 90 per cent. of mustard treatment. The other 10 per cent. requires a specialist.

OTHER WAR GASES

In the preceding pages as much detail as possible with the space permitted has been given in regard to what may be accepted as the four more important gases of the late war, namely, chlorin, phosgene, chlorpicrin, and dichlorethylsulphid.

The bulk of the chemical warfare was accomplished with them and they told more in the decision than any of the others which were used. Still others were used and served their purpose. Palite and superpalite have been mentioned as in the class of lung irritants, and while they are gravely toxic in their effects, they have not the same killing power as phosgene, and need not be accorded the same consideration.

Mention has been made only incidentally so far of the "lacrimatory gases." These were not normally lethal gases, but designed for the purpose of harassing and to make it necessary for those gassed by them to remove their masks, then falling victims to some one of the more potent gases used in conjunction with or following a bombardment with them. The bromids of benzyl, xylyl and toluyl, and other bromin derivatives were used for their tear-producing effect. They were used alone in hand grenades and in shells as a preliminary bombardment followed by shells containing lethal compounds. They were also used in conjunction with other gases, phosgene, and mustard.

Their action was powerful in low concentrations, a proportion of 1 : 1,000,000 being almost immediately effective on the eyes. They were not, save in high concentration, to be classed as lethal gases and were not used for this purpose. Our own Gas Service developed the use of brombenzyl cyanid and employed it as a lacrimator in place of the others which have been mentioned.

This gas has the advantage of much more prompt effect than the compounds already quoted, and it is insupportable for five minutes in a concentration of 1 : 20,000,000 of air, being therefore twenty times as potent as the other benzyl derivatives. It has also the advantage of great persistence, lasting for a number of days on the terrain on which it is projected.

Stannic chlorid has already been referred to in respect to its function of rendering visible the bursting of shells in attack by artillery. It had a further usefulness, viz., being, in reality, a smoke, instead of a gas, and made up of definite solid particles, it rapidly clogged the canister of the respirator and necessitated the installation of "smoke baffles" in the canisters in order that the contents of them might not become clogged and rendered useless by reason of the raising of the respiratory resistance to a point beyond which it was impossible to breathe. It was employed alone in hand grenades in "mopping up," or cleaning out dugouts which were infested by the enemy after an attack had gone on beyond them. It was also used in conjunction with the true gases and was employed in the cylinders together with phosgene and chlorin to form the wave. So thick was the cloud produced by it in this way that it was not possible to distinguish objects a meter away when enveloped by it. It had no true toxic properties.

Phosphorus was also employed both on account of the irritating smoke which it produced and for the sake of its burning effect, and was used, as was stannic chlorid, in the clearing out of dugouts and also in the formation of smoke screens.

The term "mask" has come to be accepted as a generic term for the entire apparatus employed for the protection of the face and eyes and lungs of the individual against this type of poison. Strictly speaking, it should refer to that part which covers the face, but by general acceptance it came to include all that went to make up the whole.

There were two general types or systems, which may be classed as the "single" and the "double" protection, the French mask being an example of the first and the British of the second. In the first, single type, all protection was afforded by the mask proper, that is to say, the hood which was worn over the face and which was impregnated with certain neutralizing chemicals to counteract the effect of the poison.

The double added to this impervious mask over the face a canister through which the inspired air was drawn and filtered by chemicals contained in it. A man was thus protected not only by what fitted over his face, but had the additional security of an independent source of uncontaminated air for his lungs.

The French stuck to the single system and gave as their reasons that the protection was relatively high; that the cost of manufacture was much less than for the more elaborate double apparatus, and that it was a matter of much less uncertainty to train the average soldier in the adjustment of this comparatively simple apparatus than of the more complicated one of the double system.

The British, on the other hand, rapidly got away from the "P. H." helmet, one of the earliest of their forms of protection, which was of the single type, and depended on the "box respirator," which, in addition to shielding the face by a mask of rubber tissue, guarded the lungs by means of a canister filled with charcoal and certain chemicals, generally referred to as "the neutralizing granules."

In not too extended detail the box respirator consisted of a tin canister fitted at the bottom with an inlet valve and at the top with a flexible rubber hose which led up to the face-piece and was connected thereto by a metal elbow ending on the inside of the face-piece in a rubber mouth-piece. Within the face-piece and attached to it was a nose-clip, so that inhalation was necessarily through the mouth. At the bottom of the face-piece was a rubber flutter valve through which the expired air escaped. The canister was carried in a canvas haversack which was divided into two parts, one for the canister and one for the mask itself when not in actual use. The face-piece was made of gas-proof rubber tissue, fitted with elastic straps in the form of a head harness for adjustment, and was provided with goggles for vision.

There is no doubt that this form of mask did give more protection than the single system when subjected to chlorin, phosgene, or the gases which did not attack the skin or eyes, since, even if the face-piece were torn, the lungs were still protected by the canister and tube. When it

came to the question of the lacrimators, and particularly to mustard gas, the theory in part broke down, in view of the local action of these agents aside from that on the lungs and respiratory system.

Casual consideration of the question of protection by the mask gives little idea of the somewhat complex problems which had to be solved in putting out the first of this form of apparatus and in the adaptation of it to the new gases evolved and the many requirements which service under gas attacks constantly increasing in concentration and duration demanded.

The early "boxes" made no provision for the stoppage of smoke, and with the use of stannic chlorid it was found that the canister was not only readily penetrated by this agent, but that it clogged the charcoal and rendered the box ineffective. To obviate this "smoke baffles" were introduced, first of cotton and later of more effective material, and this difficulty was overcome. The arrangement and character of the granules was changed from time to time to meet new requirements, and the product at the latter part of the war was very different from that which was at first put out. Questions of physiology had to be carefully worked out, and there was a constant endeavor to strike the logical balance between adequate protection of the individual and impairment of physical efficiency. There must always be a certain amount of lessening of efficiency with any form of protection of this sort, and the question was as to where the just mean should be struck: that which furnished enough protection without detracting too much from the physical value of the man so protected.

Anything over the face which obscures the vision and is in itself a discomfort to wear must, of necessity, lessen the normal value of the wearer, and when in addition to this he is obliged to contend with an added respiratory resistance due to breathing carried on through a box of chemicals and charcoal, there is no question as to the lessening of his value as a fighting man. But, on the other hand, it was quite essential that he be protected, up to the last reasonable degree, from the effect of the disabling gas. And so, as I have said, the problem which confronted the designers of the protective apparatus was to adjust this protection so that it should be as safe as might be consistent with fighting efficiency. In this respect there is no question that the British "box respirator" was more efficient than the mask (Type M2) of the French, and it was on the plan of the former that our own chemists and physiologists worked in designing the American protection. In the French mask the expired as well as the inspired air passed through the protective gauze of the mask, and this was clogged by moisture and the respiratory resistance quickly raised. Furthermore, the "dead space" in the M2 mask was much greater than in the British respirator, and this was an unfavorable factor. The French recognized the limitations of their system of protection, as has been stated, and adopted for the use of their artillery troops a different design of mask which had special advantages.

The best test of any apparatus of this sort was its adaptability to

the use of men who are in action with batteries, for, in addition to the great amount of labor entailed on those serving guns, the setting of sights and reading of range scales makes it essential that there shall be clear vision. The eye-pieces of the box respirator were of glass and fogged quickly, while the goggles of the French mask were of "celophane," which, while it did not have this disadvantage to so great a degree, did distort objects.

The French got out a different type for the use of their artillery and other troops specially in need of clear vision and as little embarrassment as possible. This was known as the "Tissot" apparatus, after the inventor, and was, incidentally, the forerunner of the respirator finally adopted by our own service. The Tissot mask consisted of a box of charcoal and chemicals which was slung on the back and connected by a tube over the shoulder with the face-mask which was made of pure rubber instead of the fabric used by the British in theirs. The mask was fitted with very large glass goggles, and the air, in coming through the tube, did not go directly into the mouth, but was drawn into the face-mask in such a way that it passed directly over the inside surface of the eye-pieces, keeping them always cool and avoiding the fogging which was one of the most troublesome features of the other systems.

The Tissot was, in effect, a compromise between the single and double protection; it embodied the feature of the filter box, but was dependent for its protective feature on the integrity of the face-piece. It was by far the most comfortable of any of the systems devised and easier to work in. It was manufactured by the French Government under the Tissot patent and a royalty paid the inventor. Its cost was prohibitive of its universal adoption by that government, and it had the disadvantage of being much more cumbersome than the M2.

On our entry into the war our troops were furnished at first respirators by the British, the type which was adopted on recommendation of a board appointed by General Pershing, and as our own Gas Service came into being this same respirator was turned out for our own army. Some slight modifications were made which led to the betterment of the mask as it existed at that time, and at the finish of the war, by dint of constant experiment and research, a type had been evolved which was patterned after the box respirator and the Tissot and embodied the good features of both. It was a single protection apparatus, but it eliminated the most objectionable features of the box respirator, which were the nose-clip and the mouth-piece, the constant wearing of which became almost unendurably irksome when they had to be worn for perhaps twenty hours at a stretch.

The absolute necessity for protection of this kind is evidenced in the fact that during our short participation in the war more than 3,500,000 masks were produced by the Gas Defence Division. This manufacture, even after the deliberation necessary to determine the type to be adopted, was a painstaking process in the extreme, for as the mask was the last thing which stood between the soldier and a very sure and horrid death, it was essential that each one of the 3,500,000 which was sent out should

be what it was supposed to be, a *protection*—and gas proof. The product was checked at all stages, as well as all materials which went into its make up, and, in addition to this checking, which consisted in a rigid and repeated inspection of materials and methods, frequent tests were made of masks in chambers of high concentrations of different gases. This work was done by the enlisted force and received no special commendation or mention. It was presumable, of course, that the mask would protect, but there was still an element of uncertainty and possible error which made the duty highly dangerous.

The mask, respirator—what you please to call it—was the best cure for the ills which are incident to the contact with gas; the only treatment which was at all sure and satisfactory, for with this form of traumatism prophylaxis is far preferable to any remedy, and the man who had a serviceable mask; who knew how to put it on quickly; when to put it on and enough to keep it on so long as was necessary, had gone farther along the road to subsequent life and health than he could be boosted by oxygen, phlebotomy, saline infusion, or any of the means devised to bring back to health his less fortunate brother who was exposed to the sear of this form of warfare.

Protection against gas has been divided into two general headings: Individual, which has been covered in what has just been said in regard to the safeguarding of each soldier by his own protective apparatus, and collective, which had to deal with the mass rather than the unit. As a matter of fact, the former is by far the more important of the two. In the beginning of gas warfare and when it was confined to the use of cloud gas, it was hoped that some physical means might be adopted to break up and dissipate the advancing wave, but none effectual was found, although fires, explosions, and neutralizing agents were tried. The protection of dugouts fell in the category of general protection, and this was to the end of the war a prime necessity, although methods of doing so underwent some modifications as time progressed. Cracks were sealed and entrances and exits curtained at the last as at the first, but the early practice of impregnating the curtains or blankets which formed the barriers with special solutions as neutralizants gave way to the use of plain water or that containing a proportion of some hygroscopic salt when it was found that it was the water in the curtain which kept the gas out and not the chemicals which offset the action. And so the elaborate use of the "Vermorel" sprayers and the special solutions to be squirted by them gave way to the use of simpler and equally effective measures.

With the advent of dichlorethylsulphid came, however, the need again for a chemical antidote to disinfect ground and gear contaminated by this agent, and milk of lime and the chlorid itself played an important part in the actual destruction of these local foci of infection. Gas locks were provided on the entrances to shelter, so that there was not at any time direct communication between the uncontaminated interior and the infected air without. These were the two divisions of protection: that of the individual by means of his mask, which he was

taught to use and depend on, and protection so far as possible of the dugouts in which he had to be, and the further neutralizing, so far as possible, of what had come under the blighting touch of mustard gas. The necessity went a bit further in the case of this latter gas and special clothing was designed to keep the body from being burned by it (Fig. 650), and rations were so put up in containers as not to be affected by

FIG. 650.—MAN PROTECTED AGAINST MUSTARD GAS BY RESPIRATOR, CLOTHING, BOOTS, AND GLOVES. (Chemical Warfare Service, U. S. Army.)

this agent. Further than this there was no protection, nor does it seem that there could be.

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CHAPTER LXIII

THE LEGAL RELATIONS OF THE SURGEON*

By Hampton L. Carson, Esq.,

of the Philadelphia Bar

The surgeon, as **an ordinary witness,** is subject to the compulsory subpœna of a court, and can claim no extra fee.[2] He must not confuse facts with opinions. He may refresh his memory from notes of his observations if made at the time.[4] He should be attentive to dying declarations, as he may be called upon to state them.[5] As to confidential communications, the law differs in various states as to making them *privileged* from disclosure.[6] If a judge rules that the confidence should be broken, the responsibility rests on the judge, and the doctor is relieved of the charge of breach of confidence.[7] The privilege in no state covers acts of crime.[8]

The Surgeon as an Expert.—Courts will permit the expression of an opinion, to aid a jury, even though the surgeon be not a specialist.[9] The cross-examination will determine his capacity.[9] He will not be permitted to quote books in his support, as the authors are not present for cross-examination.[12] As to special compensation as an expert we repeat the admonition of the original text. Ordinary witness fees are the rule, and many public officers have no authority to employ experts. With individuals a private contract may be made.[13] Non-medical experts, in other callings, are bound by the same rule.[14] The medical expert, however, is not bound to study the case so as to qualify himself, and can refuse to do so, but cannot escape being asked for an off-hand opinion.[15]

Bibliography on the Surgeon as a Witness[1]

1. The order of discussion of judicial decisions is the same as was pursued in the text of Chapter LXXXIV, Keen's Surgery, Vol. V, pp. 1180, etc. The references to authority are given *under the same numbers* as appear in the Bibliography annexed to the original text.
2. Commonwealth vs. Cochran, 31 Pennsylvania County Ct., 344.
4. McClendon vs. U. S., 229 Federal, 523.
5. State vs. Shapiro, 98 Atlantic, 437. State vs. Thomas, 180 Southwestern, 886.
6. Dodd vs. State, 201 Southwestern, 1014. Lombard vs. Columbia Nat. Life Ins. Co., 168 Pacific, 269. American and English Annotated Cases, 1918A, 1050. Shaw vs. City of Nampa, 171 Pacific, 1132.
7. Wigmore on Evidence: Supplement 1915, pp. 600–603.

* Supplementary to Chapter LXXXIV, Vol. V, p. 1180, and Chapter CLV, Vol. VI, p. 1016.

"In the preparation of his chapters in Vols. V, VI, and VIII Mr. Carson has consulted every reported case in the Federal and State Courts in which any new application of principle or practice occurred down to 1920" (W. W. Keen).

8. Witthaus and Becker: Medical Jurisprudence, vol. i, p. 107, 53 Hun., 217.
8a. Casson vs. Schoenfeld, 166 Northwestern, 22.
9. Wigmore Evidence: Supplement vol. 5, p. 136.
12. Chicago, R. I., and G. Ry. Co. vs. Smith, 197 Southwestern, 614. Ingwersen vs. Carr and Brannon, *et al.*, 164 Northwestern, 217.
13. Diller vs. Crawford County, 42 Penna. County Court, p. 17.
14. Flinn vs. Prairie Co., 60 Arkansas Rep., 204.
15. Lawson on Expert Opinion, 317.

MALPRACTICE

Defined in original text, Keen's Surgery, Vol. V, p. 1186, and Vol. VI, p. 1016, further illustrated.[1]

Negligence.—The not doing a thing which ought to have been done, or the doing a thing which ought not to have been done—illustrated.[2] Neglecting some act which a prudent man would have performed,[3] or doing that which a prudent man would have avoided *under like or similar circumstances.*[4] Care must be in proportion to the danger.[6] Knowledge and skill are both requisite, and both must be exercised. The absence of either is negligence. The failure to exercise both, even if possessed, is negligence.[8] The degree of skill required is that which is ordinary to the profession in the class of cases treated.[11] A specialist must have and employ the ordinary knowledge and skill in that specialty.[14] An impracticable standard of excellence is not required.[15] The standard must be such as is usual in similar localities.[20]

There must be consent on the part of the patient, or of some one authorized to consent for him, to a major operation, except in an emergency.[27] An autopsy, unless directed and required by law, calls for consent of the person lawfully in custody of the body.[33]

Neglect or abandonment of a case, without leaving a proper substitute in charge, is negligence.[39],[40]

Success of an operation is not exacted if the surgeon has exercised the knowledge, skill, and care required by the standards.[50],[51] An error in judgment, unless gross, is not tantamount to lack of skill,[53] nor is the surgeon responsible if the patient violate instructions.[54]

Negligence of the surgeon is not to be presumed from a mere lack of satisfactory results. The burden is on the plaintiff to establish the alleged lack of knowledge, skill, or care in treatment.[57]

The surgeon is responsible for the negligence of his chosen assistants.[61] If his surroundings compel instant treatment, and he does his best under the circumstances, he is not responsible.[62] If neglect in not instructing nurses lead to injury, he is responsible, unless they be nurses over whom he has no control.[65] If another be called on to take his place, he having no voice in the selection, he is not responsible.[68]

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1. Stokes vs. Long, 52 Montana, 470. Keirsey vs. McNeemer, 197 Illinois, App., 173.
2. Foreman vs. Hunter Lumber Company, 173 Pacific, 408. McGraw vs. Kerr, 128 Pacific, 871.
3. Mullinax vs. Hord, 94 Southeastern, 426.

* See footnote on page 2162, also consult vol. VI, p. 1016.

4. Fisher vs. Cedar Rapids and M. C. Ry. Co., 157 Northwestern, 860.
6. Morrison vs. Appalachian Power Co., 84 Southeastern, 506.
8. Merrill vs. Odiorne, 94 Atlantic, 753. McAlinden vs. St. Marie's Hospital Association, 156 Pacific, 115.
11. Mullinax vs. Hord, 94 Southeastern, 426.
14. McAlinden vs. St. Marie's Hospital Association, Amer. and Eng. A. C., 198A, 380.
15. Hier vs. Stites, 110 Northeastern, 252.
20. Viita vs. Dolan, 155 Northwestern, 1077. Pace vs. Cochran, 86 Southeastern, 934.
27. Rishworth vs. Moss, 191 Southwestern, 843.
33. Woods vs. Graham, *et al.*, 167 Northwestern, 113.
39. Tadlock vs. Lloyd, 173 Pacific, 200. Burnett vs. Layman, 181 Southwestern, 157.
40. Norton vs. Hefner, *et ux.*, 198 Southwestern, 97.
50. Miller vs. Blackburn, 185 Southwestern, 864.
51. Houghton vs. Dickson, 155 Pacific, 128.
53. Just *et al.* vs. Littlefield, 151 Pacific, 780.
54. Merrill vs. Odiorne, 94 Atlantic, 753.
57. Merrill vs. Odiorne, 94 Atlantic, 753.
61. Stokes vs. Long, 159 Pacific, 28.
62. Morrison vs. Henke, 160 Northwestern, 173.
65. Cassingham vs. Berry, 168 Pacific, 1020.
68. Stokes vs. Long, 159 Pacific, 28.

ILLUSTRATIONS OF THE APPLICATION OF THE LAW OF NEGLIGENCE TO CASES OF MEDICAL MALPRACTICE

Bearing in mind that negligence is the neglect of duty under the special circumstances of each case, and that neglect may consist of a sin of omission as well as commision,[1] the following specific cases may be examined with advantage by one anxious to avoid a lawsuit for damages.

Consent was presumed from the presentation of a patient for an operation, without objection to the suggestion made by the operator to the family doctor in a letter which had been shown to the patient.[2] The presence of the doctor during the operation did not make him liable for the methods and acts of the surgeon.[2] In determining whether reasonable care and skill had been used the place of operation and all the surrounding circumstances may be considered.[3] For mere errors of judgment, not shown to be due to lack of skill and care, there is no liability,[4] but if a false diagnosis might have been avoided by care,[5] or if the wrong medicine has been negligently administered,[6] or if a general practitioner risks surgery as an art, and, after an unsuccessful operation, abandons his patient,[7] there is negligence. Negligence must be affirmatively proved by expert testimony, and cannot be presumed in the absence of such testimony,[8] although some facts may be shown by non-expert testimony tending to establish negligence.[9] If ordinary care and skill are shown to have been exercised, the physician or surgeon is not a guarantor of good results.[10] There must be sufficient evidence of negligence to satisfy a judge that he ought to submit the question to a jury.[11] The death of a patient does not of itself raise a presumption of negligence on the part of the physician or surgeon.[12] Nor does the mere failure to effect a cure raise a presumption of lack of skill or care.[13] There is no insurance of a perfect result.[14]

Responsibility for Acts of Others.—A physician recommending, during his absence, another physician with whom he is not financially

connected, is not liable for the latter's negligence,[15] but where two are employed on the same case, and by agreement divide the services, each is liable for the negligence of the other.[16] A visiting surgeon to a hospital has a right to assume that the nurses hired by others are competent.[17] Nor is the operating surgeon in a hospital liable for the negligence of a hospital intern, in whose care he placed the patient, unless he expressly contracted to look after the treatment in connection with the intern.[18]

Striking Instances of Malpractice.—Unskilful use or premature removal of splints[19]; leaving sponges, gauze, or tubes in wounds or body[20]; neglect of a burn[21]; cutting the tongue in removal of adenoids[22]; use of unclean instruments[23]; failure to remove foreign matter from gunshot wound[24]; failure to detect that a nerve had been caught between fragments of broken bone[25]; failure to discover dislocations[26]; failure to keep informed of condition of patient[27]; failure to use *x*-rays where such were indicated and possible[28]; failure to use a possible slight operation to relieve pain[29]; failure to take a blood test before an operation for goiter not negligence *per se*[30]; permitting removal of patient from hospital after appearance of postoperative insanity[31]; unnecessary operation in removing part of prostate gland[32]; use of silk thread in tying arteries during operation[33]; negligent treatment of fracture, requiring refracture, though final result was good[34]; change of diet after removal of patient from hospital.[35]

In the recent case of Ætna Life Insurance Co. vs. Brand, 265 Federal Reporter, page 6, damages were given to a plaintiff where an artery running in an abnormal position was injured in an operation for hernia, and as a result of it the leg had to be amputated.

In the case of Crowell vs. Crowell, a North Carolina case, a wife was given damages against her husband for infecting her with venereal disease.

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4. Van Boskirk vs. Pinto, 155 N. West. Rep. (Neb.), 889.
5. Nickerson vs. Gerrish, 114 Maine, 354.
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13. Miller vs. Blackburn, 170 Ky., 263.
14. Baldwin vs. Gains, 102 Atlantic Rep. (N. H.), 338.
15. Stokes vs. Long, 52 Montana, 470.
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17. Morrison vs. Henke, 160 Northwest. Rep. (Wis.), 173.
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20. Wynne vs. Harvey, 165 Pac. Rep. (Wash.), 67. Cowan vs. Bonffleur, 192 Ill. App., 21. Miles vs. Harris, 194 S. West. Rep. (Texas), 839. Baer vs. Chowing, 161 N. West. Rep. (Minn.), 144. Michol vs. Winslow, 95 Atlantic Rep. (N. J.), 995. Sanier vs. Ross, 73 South. Rep. (Miss.), 49. Cyr vs. Landry, 114 Maine, 188. Talley vs. Whittock, 73 South Rep. (Ala.), 976.
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22. Evans vs. Roberts, 154 N. West. Rep. (Iowa), 923.
23. Swanson vs. Hood, 99 Wash. State Rep., 506.
24. Mullinax vs. Hord, 94 S. East. Rep. (N. C.), 426.
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28. Davis vs. Dunn, 78 Atlantic Rep. (Vt.), 81. Van Boskirk vs. Pinto, 155 N. West. Rep. (Neb.), 889. Snearley vs. McCarthy, 161 N. West. Rep. (Iowa), 108. Ingiversen vs. Carr and Brannon, 164 N. West. Rep. (Iowa), 217.
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CHAPTER LXIV

THE AMERICAN RED CROSS IN WAR AND PEACE

By Colonel Francis A. Winter, Medical Corps, U. S. Army
Late Brigadier-General, Chief Surgeon, Lines of Communication, American Expeditionary Force)

The American Red Cross has been so prominently and forcibly identified with the military and civil concerns of the recent war that it seems quite appropriate that this volume should contain a short survey of the work of the Society as seen by an officer of the Medical Corps of the Army.

The aims and scope of activities of the Red Cross are quite clearly laid down in the enactments of Congress and other official documents which affect its purposes and functions.

It may be said that to a great many among the laity the Red Cross has been held to be the sole agent charged with the care of the sick and wounded of our armies. This is probably the outcome of the trend of the ordinary mind to associate the insignium of the Society with those things which concern the sick and wounded, and there is rather a tendency to overlook the fact that both in the legislation which incorporated the Society, and in the executive proclamation which defined its sphere of activity, it is quite evidently intended to make the Society a great and efficient auxiliary to the Medical Department of the Army in time of war.

The history of the formation of the Society is interesting and will bear rehearsal. The original Society was formed under the terms of the Geneva Convention in 1881 and received incorporation at that date. By Act of Congress the Society was reincorporated in 1893. This Act was repealed by a subsequent Act dated January 5, 1905, which gave the first comprehensive and definitive statement affecting the aims and province of the organization. In order to give force and effect to the act of January 5, 1905 President Taft issued a proclamation, under date of December 27, 1911, stating, first, "That the American National Red Cross is the only voluntary society now authorized by this government to render aid to its land and naval forces in time of war"; second, "Any other society desiring to render similar assistance can do so only through the American National Red Cross." Further provisions of this proclamation established methods of operation to cover in some detail the particular function which the Society is supposed to fill in time of war.

The wisdom of this legislation and of the President's proclamation was amply shown during the period when the United States was actively participant in the European War, and it reflects great credit on the prevision of those who were responsible for having made a definite

statement of the intent and the limitations to which the Society was subject, as an auxiliary to the sanitary service of our army. It may be said in general terms and without particularizing, at this moment, that the liaison established under the terms of this legislation and proclamation was carried forth most happily and to the very great advantage of the American soldier in Europe and in this country.

During our Civil War the place taken by the Red Cross in the recent war was not exactly prefigured by any organization. The two bodies which came nearest to the idea of prototypes were the Sanitary Commission and the Christian Commission which tried to do some of the things the need for which becomes so speedily manifest once a state of war is existent.

It is interesting to contrast the great activities assumed and successfully carried forth by the Society in this war with the comparatively small identification which the Society had with the army during the Spanish War.

Some of the older officers of the army had a chance to see the Red Cross do war work in Cuba during that war, and just as that entire expedition was in the "day of small things," so the Red Cross endeavor was no great affair. As a matter of fact, it seems quite remarkable, looking back to the history of twenty years ago, that the Red Cross never followed the army into the Philippines during the insurrection. The opinion may be hazarded that such a failure to follow up the army wherever it might go at the present date is quite unthinkable, because the Society has become both a fixture and a necessary adjuvant.

The experience of the midsummer venture in Cuba in 1898 focalized some good brain power on the Red Cross problem during the years from 1898 to 1917, and the end-result of the quiet forces which exerted a sure, continual pressure on the question as to what the great auxiliary should do in war time became manifest when we got into the muddle in April, 1917. Men like Mr. William H. Taft and Mr. Robert W. DeForrest, working with Miss Mabel Boardman, gave through these years a steady impetus to Red Cross preparation and pushed on the comparatively small activity which was to extend into the great and elaborate endeavor of the war-time work. The results achieved by Mr. Henry P. Davison and his associates followed, surely and precisely, in the really wonderful amplification which was brought about.

It was, of course, necessary to work out by practical experience of the problem the exact relationships which were to obtain between the army and the Society, and it was in the successful establishment of those relationships, that the great measure of success which was achieved came to the Society and to the military establishment.

It was reasonably to be expected that a basis for conflict of authority might very readily be discovered and acted upon by the agents of the Society and the personnel of the military establishment. Such, however, was very far from being the case, and it is only putting the case properly to state that no officer of the Medical Department who had experience with the workings of the Society in Europe would be willing

to go into a like endeavor at any time in the future, without the aid of the Society to help him in the many-sided task of caring for the sick and wounded of a large army.

It is proper just here to state that the Society had made a very intelligent and comprehensive preparation extending back to the year 1915, for the contingency that this country might at some time go into the war. There was sufficient intelligence and vision in the central offices in Washington to make it apparent that the Society should take its place in the list of those organizations, which were getting ready throughout the early years of the European War to handle the task, which was to come to them immediately upon the involvement of our country in the hostilities. This preparatory work took a great variety of expression, and it is only possible in the limits of this article to refer to some of them.

Early in 1916 the Society began the establishment of so-called Base Hospital Units throughout the United States. Brigadier-General J. R. Kean, of the Medical Corps, was ordered to Washington, and placed in charge of the general effort to get together these units as tributary to large hospitals and medical schools. The roster of these hospitals, which were either entirely ready or in good process of perfection in April, 1917, is as follows:

AMERICAN RED CROSS HOSPITALS AND DIRECTORS

No.	Parent Institution.	Place.	Directors—Majors.
1.	Bellevue Hospital	New York City	Geo. B. Wallace
2.	Presbyterian Hospital	New York City	Geo. E. Brewer
3.	Mt. Sinai Hospital	New York City	Howard Lilienthal
4.	Lakeside Hospital	Cleveland, O.	George W. Crile
5.	Harvard University	Cambridge, Mass.	Harvey Cushing
6.	Massachusetts Gen'l Hospital	Boston, Mass.	F. A. Washburn
7.	Boston City Hospital	Boston, Mass.	John J. Dowling
8.	N. Y. Post-Grad. Hospital	New York City	Samuel Lloyd
9.	New York Hospital	New York City	C. L. Gibson
10.	Pennsylvania Hospital	Philadelphia, Pa.	R. H. Harte
11.	St. Joseph's Hospital	Chicago, Ill.	N. M. Percy
12.	Northwestern University	Chicago, Ill.	F. A. Besley
13.	Presbyterian and Cook Co. Hosp.	Chicago, Ill.	Dean D. Lewis
14.	St. Luke's Hospital	Chicago, Ill.	L. L. McArthur
15.	Roosevelt Hospital	New York City	Charles H. Peck
16.	German Hospital	New York City	Frederick Kammerer
17.	Harper Hospital	Detroit, Mich.	Angus McLean
18.	Johns Hopkins Hospital	Baltimore, Md.	J. M. T. Finney
19.	Rochester General Hospital	Rochester, N. Y.	John M. Swan
20.	Univ. of Penna. Hospital	Philadelphia, Pa.	John B. Carnett
21.	Wash. Univ. Med. School	St. Louis, Mo.	Fred. T. Murphy
22.	Milwaukee Co. Hospital	Milwaukee, Wis.	C. A. Evans
23.	Buffalo General Hospital	Buffalo, N. Y.	M. Clinton
24.	Tulane University	New Orleans, La.	John B. Elliott
25.	Cincinnati General Hospital	Cincinnati, O	William Gillespie
26.	State Univ. of Minnesota	Minneapolis, Minn.	Arthur A. Law
27.	Univ. Pittsburgh Medical School	Pittsburgh, Pa.	R. T. Miller
28.	Christian Church Hospital	Kansas City, Mo.	J. F. Binnie
29.	Med. School Univ. of Colo.	Denver, Colo.	John W. Amessee
30	University of California	San Francisco, Cal.	E. S. Kilgore
31.	Youngstown Hospital	Youngstown, O.	Colin R. Clark
32.	City Hospital	Indianapolis, Ind.	Edmund D. Clark
33.	Albany Hosp. and Med. College	Albany, N. Y.	A. W. Elting

No.	Parent Institution.	Place.	Directors—Majors.
34.	Episcopal Hospital	Philadelphia, Pa.	A. P. C. Ashhurst
35.	Good Samaritan Hospital	Los Angeles, Cal.	J. J. A. Vankaathoven
36.	College of Medicine	Detroit, Mich.	Burt R. Shurly
37.	King's Co. Hospital	Brooklyn, N. Y.	Edwin H. Fiske
38.	Jefferson Medical College	Philadelphia, Pa.	W. M. L. Coplin
39.	Yale Mobile Unit	New Haven, Conn.	J. Marshall Flint
40.	Good Samaritan Hospital	Lexington, Ky.	David Barrow
41.	University of Virginia	Charlottesville, Va.	Wm. H. Goodwin
42.	University of Maryland	Baltimore, Md.	A. C. Harrison
43.	Emory University	Atlanta, Ga.	E. C. Davis
44.	Mass. Homeopathic Hospital	Boston, Mass.	Wm. F. Wesselhoeft
45.	Medical College of Virginia	Richmond, Va.	Stewart McGuire
46.	University of Oregon	Portland, Oregon	Robert C. Yenney
47.	San Francisco Hospital	San Francisco, Cal.	Charles Levison
48.	Metropolitan Hospital	New York City	Wm. F. Honan
49.	University of Nebraska	Omaha, Neb.	A. C. Stokes
50.	University of Washington	Seattle, Wash.	James B. Eagleson

Each of these hospitals was made up of a personnel of 23 medical officers, 65 nurses, and 150 enlisted men, and each hospital was designed to look after the needs of 500 sick and wounded. It is well known to all students of military medical history that the attention accorded the sick and wounded of the American Army during the Spanish War was, to say the least, insufficient and justly subject to much criticism. If the like reproach has been spared the Medical Department of the Army during the present war, it is safe to say the average observer of experience will pass a large measure of the credit for that exemption to the fact, that these Base Hospital Units were so carefully organized and so abundantly fitted to look after the sick, and avert just such criticism as came during the Spanish War.

The professional side of the units was most admirably balanced, and comprehended in its make-up experts in all of the specialties of medicine. The rosters showed the very best of America's medical men.

The institutions were fashioned to function as General Hospitals, wherein a soldier could obtain treatment of the most skilled variety for any and every disease or injury with which he might be afflicted. Over and beyond the strictly professional attainments there is to be placed the fact, that the medical men making up these units were of such superior moral fiber. It is needless to speak of the great step forward which was made in securing the services of this kind of men.

Again, it must be remembered that the nurses and enlisted men were selected with the very greatest care. There was plenty of time to cull out undesirables who might seek enrolment, and it is safe to say that no finer body of people, taken in their entirety, was ever assembled than the personnel of these hospitals. The rather trite observation among those familiar with the situation, that had the Red Cross done nothing else in the war, it would have earned its keep by the fact that under its auspices, and backed by its great power to prevail these units were collected, has in it a full measure of truth. It is to be remembered that there was no provision in law by which these organizations might have been formed as elements of the military forces, authorized by Congress, and it was just in this provision of a central governing body, under which

the units could be assembled in time of peace, that the Red Cross supplied a great desideratum at the particular period when it was so much needed.

A further measure of preparation was taken in the establishment of so-called "Lettered Units," which might be properly characterized as adjuncts of carefully selected personnel, to augment the personnel of a strictly Base Hospital Unit. In many of the smaller cities of the country these Lettered Units were established as tributary to local hospitals, and carried with them approximately 10 medical officers, 30 nurses, and 40 enlisted men. The intent was to use these units in extending the range of action of a Base Hospital, when the expansion of function, which was clearly foreseen, should come to the base hospital organizations designed for only 500 beds.

This plan did not work very well because the "Lettered Unit" was averse to absorption into the Base Hospital. A better result would have come from designating these smaller units as personnel to staff camp and other hospitals of 200 or 300 beds, or as surgical units with given areas to attend to.

Another very outstanding service rendered by the Society took form in the establishment and extension of the nursing service. This work was inaugurated by Miss Jane Delano, who died in France in April, 1919, and it has seldom been given to any woman to leave a more substantial and fitting monument to her activities, in this life, than that which came to Miss Delano, in connection with this service.

Her plan contemplated the scrutiny and careful observation of great numbers of trained nurses in this country with the view to enrolling them for service with the Red Cross, whenever they might be called upon to render that service. It is needless to say that the ease with which well-qualified and well-poised women were sent into the army for work in military hospitals from this service, was of the very greatest benefit to the military establishment. Again, the conditions which obtained during the Spanish War, when the needs of the service had to be met in great haste and without due time for the investigation of applicants, resulted in the employment of many persons as nurses who were, to say the least, very poorly qualified for the work which they assumed. Under the influence of Miss Delano's careful investigation of applicants there was little or no embarrassment coming from the selection of material of improper stripe.

Of course, it was well known that these groups of personnel could not function properly without an adequate and up-to-date scientific equipment. Both by Red Cross solicitation and by the personal efforts of the directors and other professional personnel of the units, very considerable sums of money were obtained by popular or private subscriptions in the communities which furnished the personnel. In many cases these funds enabled the organizations with due care and timely criticism to obtain the very best medical and surgical equipment which the American market afforded.

It thus followed that at the time of mobilization practically every

one of these units had in storage a most elaborate and comprehensive armamentarium, including everything required for modern medical and surgical practice.

It is needless to speak of the very great benefit which came from this effort and to contrast it with what might have been true, had it been necessary at the time war was declared for all of these organizations to get into the market for equipment, on a competitive basis.

The financial side of the endeavor in the days of preparation was, of course, a most material consideration, and cleverely managed campaigns, resulting in the subscription of large sums of money, put the Society on a very comfortable basis when the time came for it to cast in its lot with the army, and during the progress of the war.

Another great measure of substantial preparedness lay in the selection of the personnel to carry on the general administrative affairs of the organization. Judging from the happy result which always followed contact with the agents of the Society, it is fair to assume that the greatest care was given in the selection of these men. They came from the most solid and influential positions in America, and no measure of preparedness could reasonably be held as more effective, than that which gave to the Red Cross so many competent men, who willingly went into active service when and where they were needed, and generally without financial compensation.

It seems to me that the activities of the Red Cross Society in Europe during the period of the war may be properly considered from the standpoint of its military endeavor and from that of the assistance rendered the civil population in the devastated countries.

It was well in the mind of the gentlemen charged with the direction of the affairs of the Society, that its sphere of action was to be properly confined to the area of the Base and Lines of Communication, and, in general terms, it was so limited. To make this matter clear, it may be pertinent to say that the organization of the Lines of Communication area, in the American Expeditionary Forces comprehended the strictly base ports, such as St. Nazaire, Bordeaux, Brest, Havre, La Rochelle, and Marseilles, with the British Isles as a separate section.

These base port sections were concerned with the reception of all supplies and troops from the United States, and were, of course, in turn, delegated to take over the task of returning to the United States the troops, which had been sent over in the early days. Further up the lines a large area was segregated as an Intermediate Section of the Lines of Communication, and just back of the zone of the army proper there was established an Advance Section. The function of the Intermediate Section and of the Advance Section was principally concerned with the storage and forwarding of supplies and personnel, and in all of these areas the activities of the Red Cross were speedily gotten under way and carried forth effectively, always in close liaison with the Medical Department of the army.

It may be said here that the attitude of the Commander-in-Chief was most sympathetic to this arrangement; but it was to be desired that a

closer definition of the interlocking functions of the Red Cross and the Medical Department should have been given early pronouncement, and it is suggested that the liaison with General Headquarters should have been maintained through the Medical Section of G 4 of the General Staff.

Naturally, the activities of the society as related to the army should be considered under the special heads in which these activities found expression.

First and foremost, the question of medical supplies presents itself. As noted above, the Society had made good provision in connection with its prewar work, and had gotten together big stocks of stuff, of infinite variety, into warehouses in France, before the American Expeditionary Forces came on the scene, and these stocks were perfectly priceless to that force in the early days and later, when hazardous shipments from the United States failed to arrive. It is easy to recall, for instance, the time when the expected and indispensable shipment of ether for hospitals failed to show up because of the submarine toll, and everybody felt so much easier when 20,000 pounds were shipped from a Red Cross warehouse in Paris to the depot at Cosne, thence to be distributed as might be determined. Pajamas were lacking at one time, and it was very consolatory to find, on a visit to supply depots of the A. E. F., that the call on the Red Cross had been responded to in so very substantial a fashion that 75,000 pairs of outing flannel garments were stored in the warehouse.

A board of clever American surgeons, under the direction of General Bradley, Chief Surgeon, American Expeditionary Forces, and with Colonel W. L. Keller as its immediate head, compiled a manual of splints, demonstrated by our Allies and our own people to be the proper agencies in the surgical treatment of gunshot and other fractures. The Red Cross published this book and did more. The descriptive matter was not of much value without the actual apparatus, so a Red Cross splint factory grew up in Paris, where thousands of the most modern adaptations for patching up maimed soldiers were produced and shipped out.

If one thinks it a matter of mere flashing the Aladdin lamp of money to get a splint factory going in a country depleted by three years of war of everything in the metal line, let him try it and he will ungrudgingly commend the people who effectuated this enterprise.

Well up toward the front at Neufchateau, for instance, the Red Cross early provided itself with warehouses, which were well stocked with stuff to help out, and when division surgeons—those with troops at the front—needed emergency supplies, because of delays on the overcongested railroads of France, for instance, they mostly had a generous uncle in the local Red Cross man. One overprovident division surgeon had to leave behind him many truck loads of first-class stuff, contributing greatly to the comfort of his sick people, when the order came for his outfit to move, and not a little of this stuff could be traced to the able-bodied Red Cross man who tended the sector of that division.

Motor transport was often a very scarce article in the days of the American Expeditionary Forces, especially in the early times when the army had not struck its automobile stride. Many a gallon of gasoline did its little bit for the cause, in machines which the influence of the Red Cross pulled out of the blue sky. Just how the Place de la Concorde obtained motor transport is somewhat of a mystery, but it showed up when the need was often very great. Many an American consultant, whose consulting fee to the city patient at home was no negligible matter, got to serious cases on time, and at one of our hospitals in some little remote French town lifted the weight off the heart of the sick or wounded youngster, who needed and knew he was getting the best medical help in the world. As often as not this help was sent to him in one of the "mystery cars" of the Red Cross. The statement has been made that these "Lady Bountiful fellows" got their cars by virtue of their great wealth, but the transport was priceless and it needed more than mere money, of which there was pretty generally a surfeit, to get an actual motor car fit for service.

If there be any criticism to be made of the activities of the Society so far as supplies were concerned, it lies in the fact that some of the Red Cross agents were somewhat too keen to distribute material to any one asking for it. This spirit of co-operation, if it be an error at all, was one of overzeal, and if that spirit is to be criticized, it should be done with the velvet hand. Undoubtedly there were excess accumulations of material at some points among the divisions, and it is easily figured out that this excess accumulation resulted from the combination of a too receptive and overprovident Division Surgeon and an overbountiful local representative of the Society. The harm done came from the distribution of too much material at one point, with a possible deficiency resulting to the man who came later for supplies, and a measure to obviate this error will be suggested later on.

One difficulty in the early days of the American Expeditionary Forces lay in the fact that there was apparently a lack of co-ordination between the activities of the Red Cross and the Supply Division of the Surgeon-General's Office in America. It was apparent that many things needed in Europe and which might very readily and appropriately have been supplied by the Red Cross were not relegated to that source. Upon representation that such a liaison was much to be desired, it was speedily effected on the American side of the water and the needs in particular lines of material were very speedily met by the concurrence of idea and efforts which followed.

The war spirit which came over America impelled a great many women to contribute their services in any and every capacity to the cause of the country, and it was a fortunate thing that the Red Cross supplied them with a medium for the intelligent application of this spirit. By systematizing their working hours, and delegating to them the production of articles of real value to the soldier, a most happy result was arrived at. A reasonable and appropriate balance was kept on the production of bandages. Surgical dressings of various kinds,

made into suitable front and rear line parcels, were an especially important item of production. These dressings were assembled into packages designed for use at various points along the front and in the hospitals in the Lines of Communication, and having been carefully gotten together and made ready for immediate use, it is readily seen what a very clever idea was embodied in the transaction.

Further than this, the energies of these patriotic women were directed to the manufacture of pajamas, convalescent suits, and such like articles of clothing as were urgently and constantly needed in hospital service. It is not too much to say that this service and the systematizing of these efforts were of the most lasting benefit to the army.

In the supply of cash funds for emergency purchase of delicacies and other food items, for soldiers sick in hospital, the Red Cross was of the very greatest assistance. It happened not infrequently that a local shortage in money came about and the immediate supply of funds, upon requisition by medical officers, sanctioned by the Chief Surgeon, was of very great assistance.

It was found in the A. E. F. that the Red Cross was of great assistance in the procurement of certain technical supplies, such as laboratory materials. They were able to go into the markets and by very ready methods procured supplies which were much needed in emergency and which were of very great help in the early days of the Expeditionary Forces.

The Society was also able to do a great deal in the matter of providing buildings for the housing of Medical Department activities, whether by purchase or rental of existent buildings or by improvisations, from the scanty building materials obtainable in France and England. This found expression in the provision of rest houses and such like conveniences and in the emergency supply of shelter for hospitalization. In the city of Paris the Society procured, and turned over to the army for operation, three very excellent hospitals. One of these was the famous Neuilly plant, which had been originally operated as the American Ambulance, under the control of Dr. Joseph A. Blake, of New York, at first, and afterward, of Dr. James P. Hutchinson, of Philadelphia.

In England the Society erected a very beautiful 500-bed hospital at Mossley Hill, in the suburbs of Liverpool, and the entire construction of this admirable plant was carried forward exclusively by Red Cross agents. Another site was secured in the south of England at Sarisbury Court, near Southampton, and when the armistice was signed 1200 beds were quite ready for occupancy at this point.

It happened on many occasions that Red Cross agents were able to secure very suitable buildings for army medical activities and the funds of the Society were quite judiciously employed for the military establishment in these efforts. It is needless to say that this meant a great deal, and the ready methods by which the work was done through the French and British kindred societies were of extreme importance and the greatest benefit to our forces.

In the general matter of Red Cross assistance it is felt that this war

has demonstrated the fact that there should be a controlling agency between the producer, represented by the Red Cross, and the consumer, represented by the local medical officer, who is to use the materials supplied by the Society. Some such central control was demonstrated to be necessary because of the overprovident spirit manifested by many local medical officers, and the overgenerous distribution made by local Red Cross agents, which has been previoysly referred to. In order properly to carry out any such liaison, without putting too many official blocks in the way of the flow of supplies, or, on the other hand, encouraging prodigality, the matter should be placed with the highest medical authority within given areas, and this was done by making the Chief Surgeons of the different Sections in the Lines of Communication, and the Division Surgeons on the front lines, the arbiters in such matters. It will never be possible to work this out to an ideal result, but undoubtedly the best results in the situation will ensue upon such an arrangement as this.

There is, of course, to be considered the disposition of the Red Cross men to avoid criticism due to any lack of comforts and supplies going to the individual soldier. It is only human that the agents of the Society should try to avoid this. On the other hand, everything used in the transportation of Red Cross supplies must, of necessity, represent so much transportation denied to other military necessities, and prodigality by the Red Cross necessarily reacts on the whole military institution.

In this matter, as in most others, where men are charged with interrelationships the intelligence and adaptability of the personnel will, after all, secure good administration or bad, just as those qualities are present or absent.

In the establishment of canteens and rest stations along the lines of railroads in the areas to the rear of the armies, the Society found one of its most valuable lines of work in France and England. It meant a very great deal both to the morale and the physical well-being and comfort of soldiers, that they were able to find at so many railroad stations, intelligently placed along the lines of travel, points where they could obtain refreshment in the way of food, and emergency assistance for the correction of states of illness. These canteens were staffed by a very intelligent and capable personnel, principally recruited from the very best class of American women, and this line of work is to be most emphatically commended, both during this war and for the future.

The scientific contributions of the Society to medicine and surgery were most material in Europe and under the direction of the Chief Surgeon of the American Red Cross, and with the hearty co-operation and assistance of the Chief Surgeon of the American Expeditionary Forces, there was established a Research Society, which met in Paris at stated intervals, as a forum for the discussion of various questions of medical and surgical interest and value. The meetings of this Society were attended by all officers of the Medical Department in the American Expeditionary Forces who were able to get away for brief periods from their local duties, and a great deal of very valuable knowledge

was imparted and able and searching discussion was fostered and carried forth. This Society furnished the opportunity for comparison between methods in use in the British and French service with those which pertained in our own army, and most excellent results followed upon this line of policy. A great deal of the fine work of the Inter-allied Surgical Congress was promulgated at these meetings.

It may be mentioned in connection with this Research Society that some of its members were constituted into a commission, under the Chief Surgeon, American Expeditionary Forces, to investigate the etiology of trench fever, which, as a cause for morbidity, had ranked very high; especially in the British forces, along the northwestern lines. As a result of this investigation it was established beyond doubt that the body louse carried the infection, and it is needless to say that the promulgation of this definition was a great spur in showing the importance of delousing, and a great factor in lessening the quota of men withdrawn from military service by reason of the temporary disability due to trench fever.

The journal maintained by the Research Society gave a comprehensive survey of the progress of military medicine and surgery both in our army and among the Allies, by furnishing a medium for the immediate publication of the scientific contributions, of the many distinguished medical men who made up the quota of the Medical Corps, on duty in the forces.

It was a wise provision which secured the services of representative members of the Medical Corps as Chief Surgeons of the Red Cross. By this means the head of the Army Medical Department was in constant touch and close relationship with the medical activities of the Red Cross, and it thus became possible to co-ordinate these activities, and at the same time there was provided a most effective liaison, for the statement of needs and the establishment of policies which the military situation required. While there was, of course, the closest communication between the laymen who were at the head of the society, it was very appropriate that there should be a channel of approach to these gentlemen which, while lying within their own organization, was none the less very close and sympathetic with the point of view of the medical officers on the staff of the Commander in Chief.

The work of the Society among the civil population in the area of enemy occupation during the war greatly exceeded any previous performance of any similar organization along these lines of effort. The relief brought to the wretchedness everywhere blighting these areas was incalculable, and no territory holding the stricken people of the Allied nations went untouched by the energetic agents of the Society. It was their task to sustain body and soul for these people, from whom most of the things that make life worth living had been ruthlessly and cruelly taken away. Belgium, Serbia, Italy, Russia, and Rumania were all helped and sustained by well-organized systems of relief.

So far as the future relationships between the military establishment and the Red Cross are concerned, one may say in general terms that the

methods pursued during the war in Europe were, in the main, very satisfactory. There are certain features which may merit and should receive amendment and change.

It is open to discussion as to whether our army and Society should not pattern their solution of the transportation question after the method adopted by the British in France. It is true that the British Army turned its convoy ambulance service over for administration and operation to their Red Cross Society, and very diligent inquiry shows that this measure was quite satisfactory in the handling of their wounded. The Society recruited the personnel, furnished the ambulances, and carried forth practically the entire problem of the transportation of patients. They were, of course, under the direct control of the Army Surgeon, and it would seem that the question of change is worthy of careful consideration in our service.

There is no reason why Red Cross Ambulance Sections may not be organized and kept to the quota during time of peace, to be turned over to the army and operated by the Red Cross during the period of war; but should this change come about, there should be no question that the control of these organizations by the Medical Department should be definitive. This is entirely compatible with the raison d'être of the Red Cross military activity.

The question is also advanced at times as to whether the Society should undertake the operation of all Base Hospitals in the Lines of Communication. It is not thought that this suggestion has much to support it, because the personnel operating the hospitals and the personnel which makes up the patients in the institution must of necessity be under very emphatic military control. Further than this, it is quite true in the military as in other fields of activity that "good wine needs no bush," and the eminently satisfactory results which came from the operation of these Base Hospitals by the military authority, both in France and England, puts that method of operation on a basis where it may be rated as entirely satisfactory, and there certainly seems nothing to warrant experimentation in time of war to justify departure from a system which has been found to be most effective.

The plan pursued under which, as sketched above, the Red Cross recruited and prepared the Base Hospital Units to be turned over to the army for operation has proved so very satisfactory that it would be a dangerous expedient to attempt any other method for getting a satisfactory result.

It is much to be desired that storehouses of the Medical Department and the Red Cross be located closely together. This would facilitate the supply problem very greatly, and it requires only a little thought to make it clear that transport, administration, and issue of supplies would severally prosper by such an arrangement.

Joint action would vastly systematize the situation and obviate duplications of issues and other prodigalities. I believe such a conjunction could be easily brought about without abridgment of the function of either the army or the Red Cross.

Along the lines sketched in this brief survey it is believed that the Red Cross could proceed very satisfactorily in the forthcoming years of peace to prepare itself for co-operation in the event of any future war. It must be borne in mind that its services to the country were of incalculable value; but by the same token, the cordial and abundant response in money contributions made by the country to the Society was made primarily to assist our soldiers, and it imposes and carries with it a great obligation, that there shall be unceasing effort to get as good, if not better, results during a possible future war as came from the effort of the Society during our recent involvement. Nothing will help this effort more effectively than a close concert of plan with the Medical Department of the army.

On the score of peace activities, the endeavor of the Society at the present time to interest itself in the propaganda for better health conditions in civic and rural communities within the United States, and to a certain extent in foreign countries, is commendable. This activity must, of course, be approved by anyone interested in the general uplift of our people, and the training which the agents of the Society may obtain in working out this concern, may easily be of great advantage to them in time of stress, whether from the hazards of war or those of peace. This activity in time of peace seems to be very closely connected with the flotation of a rural nursing service embodying along with its nursing activities an opportunity for the instruction of local communities in the principles of elementary hygiene and surgical and medical first aid. This work seems to be connected to a quite considerable degree with the activities of the Public Health Service.

Judging from the work the Society has done in the past, it would seem very appropriate that its function in time of civil disaster should be constantly borne in mind. Certainly the contribution to the well-being and the salvage of the victims of the flood disasters in the Ohio and Mississippi Valleys, during 1913, particularly in its provision of medical personnel, should be an earnest of the immense amount of good which the Society can do along just such lines. It would appear that the accumulation of the stocks of materials designed for medical and surgical relief during the quiet period, when it should be possible to accumulate them in a leisurely, careful fashion, and without great competition in the markets, should not be forgotten.

A great field as yet untouched may be found in time of peace in the organization and training of surgical teams in all communities to function in times of disaster of any sort. These teams should consist of two surgeons, two surgical nurses, and an anesthetist, and every community should be searched out, the best personnel enrolled, and the cadre of the teams kept constantly ready for work at points within a short radius of the home station of the team. What these teams learn in time of peace could be carried as a vast asset in time of war. Equipment for easy transport in time of stress should be provided and the full detail of the measure could easily be worked out.

The "atuo-chir" as developed by the French should be considered in

connection with the function of these teams. In the midperiod of the war the French assembled a surgical equipment carrying full operative armamentarium and *x*-ray equipment to be housed in tents and readily transportable on motor trucks. This equipment was very mobile, of course, and was of the very greatest service in providing a readily transportable material to meet a stress of conditions in any one sector of the battle lines. The personnel and equipment were more or less flexible and not governed by any hard-or-fast lines, the general idea being to provide emergency surgical relief of extensive quality at any particular point, where such relief was made necessary by the unusual stress of battle conditions at that point.

In general terms, the Red Cross has become in a large measure a national necessity, and from the small beginning manifest in 1898, the succeeding twenty years have given an earnest of the enormous possibilities for good which rest with a national organization of this character. Those who have had the Society under close observation know the scope of its work and the manner in which the work has been performed. It is not too much to say, that no Medical Officer of experience would be willing to go into a war situation without the conscious sense of relief which would necessarily come to him from knowing that he had so good and so potent an organization as the Red Cross to assist him in his efforts.

The American Red Cross has by no means the only organization which alleviated the sufferings and ministered to the wants of our soldiers. The work of the Young Men's Christian Association, of the Knights of Columbus, of the Young Men's Hebrew Association, and of the Salvation Army was of incalculable value. I have only included an account of the work of the Red Cross because it is the only Society which by law is officially co-ordinated with the Medical Department of the army, because of its being an International Organization, because of the magnitude of its work, and of its more evidently surgical character.

The bravery and devotion of the women nurses was beyond praise. When hospitals were repeatedly and intentionally bombed—*more germanico*—instead of yielding to fear or hysteria they continued at their posts, by their own calmness promoting the speedy evacuation thus rendered necessary, and some of them gave up their lives—heroines of "duty before safety." It is also only just to add that, as a rule, many women who were not nurses rendered equally brave and commendable service.

CHAPTER LXV

NOTE ON A SIMPLE, CHEAP, SELF-MADE, AND EFFECTIVE METHOD OF DRESSING AN INGUINAL ANUS, WHICH HAS STOOD THE TEST OF TWENTY-SEVEN YEARS OF SUCCESSFUL USE

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Patients with an inguinal artificial anus have the greatest difficulty in preventing their being disgusting to themselves and to all about them. They find great difficulty in obtaining employment, since no one is willing to be near them or work with them.

Expensive and often clumsy apparatus for preventing the escape of feces, or reservoirs for catching it as it escapes, especially when the movements are liquid or even semiliquid, are never successful so far as I know, and I have seen a number of them.

A patient on whom I operated many years ago has completely solved the problem by a method which is cheap, simple, self-made, and efficient, as an experience of twenty-seven years has amply demonstrated. In this long period he has frequently been to see me and has sat within three or four feet of me, but never even once have I detected a single whiff of offensive odor. He is an active business man, goes everywhere, attends his Yale class reunions, yet his misfortune never betrays him.

He first consulted me in December, 1892 for a trouble which on examination proved to be an already extensive cancer of the rectum. On January 6, 1893 I performed a Maydl operation, securing in place a small loop of the colon in the left inguinal region. A few days later I divided the bowel completely, thus establishing an inguinal artificial anus.*

On January 18, 1893 I did a Kraske resection of the sacrum and of the rectum, including the anus, which could not be saved, and established a perineal artificial anus. He was up on the fifteenth day and went home soon after. A microscopic examination of the specimen confirmed the clinical diagnosis of cancer.

February 16, 1900 I closed the perineal anus, as its frequent prolapse was exceedingly annoying.

In a recent letter to me, written at my request, he says: "The bowel ends protrude, normally, about $\frac{1}{2}$ inch outside the wall of the abdomen (Fig. 651). The end of the unused lower part of the bowel does not vary in size; it is inert. The end of the upper, active bowel is like it when conditions are normal. I have fairly regular movements every morning, de-

* The case was first published in the Therapeutic Gazette for 1897, p. 305 (Case 3). Later in the Jour. Amer. Med. Assoc., May 10, 1913. By a clerical error the date of the operation was then given as December 14, 1892.

pending, of course, somewhat on regular habits of diet, which also affect the character of the discharges as to their being formed or semiliquid. My motions are never under control as with a normal sphincter. At the same time they give me fair warning. If formed, they do not hurry me, and in cases of necessity, as when traveling, I can carry a movement for hours. But if semiliquid or worse they must be cared for promptly.

FIG. 651.—THE TWO ENDS OF THE DIVIDED BOWEL AT THE INGUINAL ANUS TWENTY-EIGHT YEARS AFTER OPERATION.

"Now, as to protection. You are right in wanting this in detail. Lying on my back with the bandage spread out under me, I first wrap a string of absorbent cotton around the bowel ends (Fig. 652). Then I place over the abdomen a layer of cotton about 6 by 9 inches, reinforcing

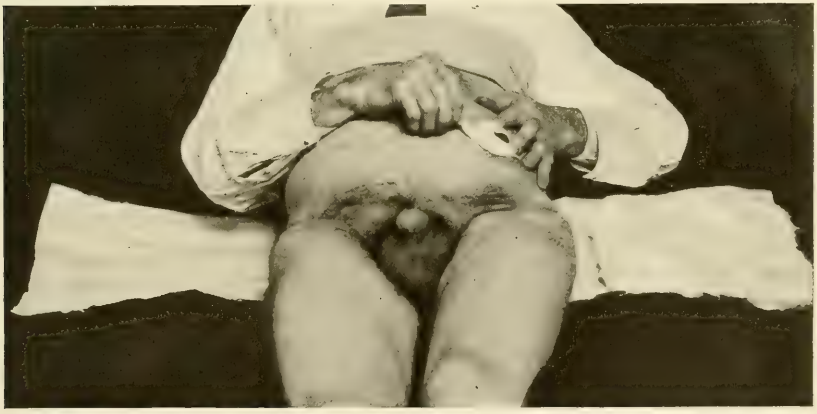

FIG. 652.—SHOWS THE MODE OF WRAPPING THE ENDS OF THE BOWEL AND THE DRESSING LYING UNDER HIM.

it at the bottom with another strip 3 inches wide to make it of double thickness. This gives better support to the flange of the truss and increases absorption. Over this pad I lay another piece of cotton or linen cloth—any clean old rags will do—then another sheet of cotton, split thin, then another cotton rag, and on this a square about 4 by 5 inches

of rubber cloth (Figs. 653, 654). These cotton pads extend one-third of their length over the bowel ends to the right and two-thirds to the left and down the side, as it is in the latter direction that the movements spread most.

"Then I bring the bandage over from the right side, overlap it with the end from the left side, and fasten it with five safety-pins $1\frac{1}{4}$ inches long, beginning at the bottom and drawing it fairly tight. I then bring

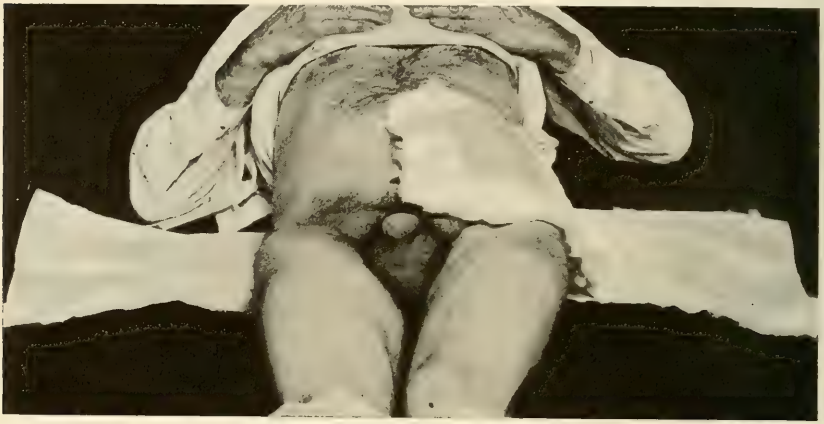

FIG. 653.—NEXT STEP. (See text.

FIG. 654.—NEXT STEP. (See text.)

up the split ends of the T and fasten each end to the lower edge at the encircling bandage. The bandage should not cover the lower edge of the pads by $\frac{1}{2}$ inch (Fig. 655). This is a good deal of detail, but it is all important. The cloth square between the pads catches the moisture which goes through the cotton, and the one under the rubber will be wet while the cotton under it is dry. The rubber protects the bandage when the discharge is profuse. In dressing a movement, I simply fold back the cotton not soiled and gather off the feces with a square of

soft paper, cleanse with part of the cotton pad, and redress with new as may be necessary.

"Next, standing, I adjust my truss (Fig. 656); and let me say here that a truss is an absolute necessity. It is the only insurance against dis-

FIG. 655.—ABDOMINAL BANDAGE AND T-BANDAGE APPLIED.

astrous leakage down into the clothing of liquid feces. It constricts the lower edge of the bandage, holding it tight to the groin and making the bandage and pads a safe reservoir even with liquid discharges, if they are not too profuse. Of course, if they are profuse all pads will be

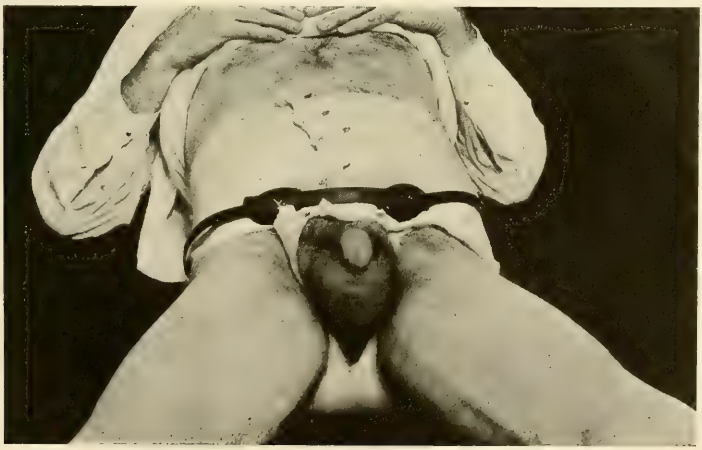

FIG. 656.—FRONT VIEW, SHOWING DRESSING AND TRUSS.

saturated, and sometimes there will be leakage. But it must be a bad discharge that gets so far.

"You will find a horizontal slit in the middle of the wide bandage opposite the spine. This is to catch the edge of the back flanges of the

truss and prevent the truss from slipping down—another important detail (Fig. 657). The bandage I send you is made up as I use it. Open it carefully. The patient must keep a few on hand. It is made of 40-inch brown muslin. The strip half as wide as the bandage makes the two T's.

"The discharge from the opening of the lower part of the rectum is negligible. [The perineal end of this part, it should be remembered. was closed in 1900.] Once in a great while I find on the pad a thimbleful of gray matter, soft and odorless. Once I thought there must be some accumulation of it and I tried to void it by hanging down, head to the floor from the foot-rail of my bed and manipulating the posterior end

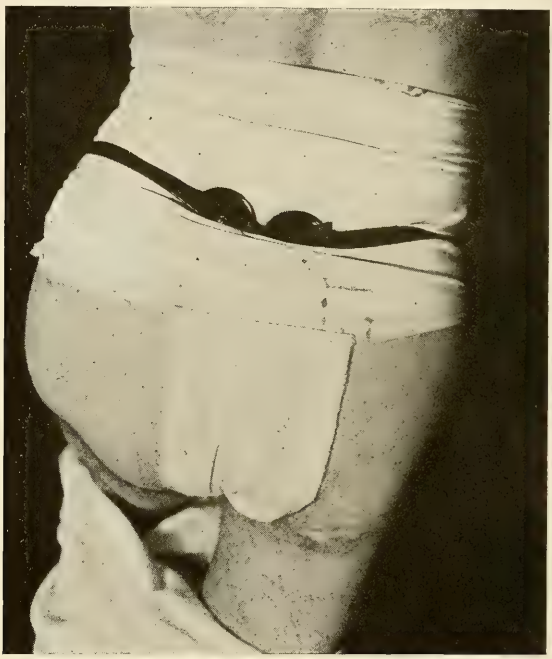

FIG. 657.—BACK VIEW, SHOWING TRUSS AND DRESSING. THE LOWER EDGES OF THE BACK FLANGES ARE CAUGHT IN THE HORIZONTAL SLIT.

with my hands, but with no result; so I ceased to bother about it. I regard it as a 'closed' incident. It gives me no pain except sometimes when it swells when I strain my abdominal muscles to effect a movement."

I should not again call attention to this case were it not that the method which he has evolved is so absolutely satisfactory and yet seems not to have attracted the attention of surgeons in general. But every patient with an inguinal anus will be more than thankful to obtain relief from such a disgusting condition, and every surgeon who tries this method will be delighted to bring such complete comfort to his patient.

As to defecation he writes: "My management of defecation depends upon the character of the feces. If solid or semisolid, I stand at the seat of my toilet, fold both shirts up above the upper edge of the bandage, loosen *three* upper safety-pins, fold down the bandage with the upper layer of cotton pads, the lower layer holding the feces. With these I wipe off the feces. I then wet some waste cotton, like a sponge, and cleanse the abdomen and bowel ends; replace the soiled cotton by a new layer if necessary (first wrapping the bowel ends again), fold up the bandage, and repin it.

"If the movement is very soft and profuse I take the bandage off for more complete renewal of the cotton pads, after which I replace it by lying on my back in bed, as before described.

"The above explains why I use two layers of cotton separated by clean rags. Two layers are an insurance of greater safety and only one layer need be wasted.

"I have in my store a retiring closet with a shelf like a Pullman berth and a box like this ◢ to lean against while lying down, a pan of water, and a box of supplies. I lie on my back, loosen and spread out my bandage, wipe off the feces, cleanse, and replace as above. The feces and spoiled cotton are simply rolled up in a big sheet of waxed paper.

"One incidental advantage of the bandage arrangement is that the constriction of the truss on the lower edge of it enables me to carry a movement if necessary for hours (*e. g.*, when traveling) until I reach harbor again.

"Much depends upon care in diet. I have occasionally had fermentation of the bowels, when the feces came in gushes, with evident consequences; but in such a case I judge that the rubber bag would be no more protection than my absorbent cotton, and vastly more difficult to cleanse and deodorize. But every patient has his own digestion and his own bowels to deal with, and the injunction 'know thyself' is most appropriate. Every patient must use his own wits and experience.

"I frequently have to stimulate or complete an evacuation by rubbing (or kneading) the abdomen and by pressure of the hands to squeeze out the contents of the bowel, but one soon learns when the job is done. I do not think I average more than a daily movement, and I try to secure this in the morning. If my bowels are inactive, a cup of hot water first, then my cup of coffee at breakfast and my pipe or cigar going down to business generally effect the desired result. Cathartics should never be resorted to.

"I am afraid I have given you more detail than you will want to print, but it is the detail that makes for convenience—and safety.

"I have never found any use for a bed-pan."

I quote his description in detail, with a number of serial photographs of the different stages in the dressing, for, as he rightly says, every detail, even the smallest, is essential to success. A "dummy" truss, if the patient has no hernia, is indispensable to success. He calls it "the key to the situation."

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